



**U.S. Army Corps of Engineers  
Walla Walla District**

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# **Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.**

## **Part 8: The Dalles Reservoir**

### **FINAL REPORT**

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**M.C. Richmond  
W.A. Perkins**

**Battelle Pacific Northwest Division  
P.O. Box 999  
Richland, Washington 99352  
Contract DACW68-96-D-0002**

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## **Abstract**

One of the major goals for the U.S. Army Corps of Engineers Dissolved Gas Abatement Study is to identify measures that could reduce levels of dissolved gas supersaturation in the Columbia and Snake Rivers caused by spillway discharges. Attaining this goal could contribute significantly to meeting water quality criteria and lowering gas bubble trauma in resident and migrating fish in these rivers. To achieve this goal, the Corps of Engineers is studying various operational and structural alternatives using field investigations and computational modeling tools to simulate the transport of dissolved gas in the river system.

Part 8 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to The Dalles Reservoir of the Lower Columbia River system.

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## **Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.**

### **Part 8: The Dalles Reservoir**

Under Biological Services Contract DACW68-96-D-0002, Delivery Order No. 8, Battelle, Pacific Northwest Division is developing and applying a two-dimensional hydrodynamic, transport model, and fish exposure model to the Lower Columbia and Snake River systems. This work is an element of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program (DGAS).

Part 8 of the report series describes the application of the model to the The Dalles Pool of the Columbia River. The modeled domain encompasses the following region:

- John Day Dam, at Columbia rivermile (RM) 217
- The Dalles Dam, at Columbia RM 192

## **1 Application of the Hydrodynamics and Water Quality Models to The Dalles Pool**

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Columbia River that forms The Dalles Dam pool. The model simulates time-varying distributions of the depth-averaged velocities, water temperature, and total dissolved gas. Further details concerning the model including the governing equations and solutions procedures are provided in Part 1 of the report series (Richmond, Perkins, and Scheibe, 1998).

The section discusses the general aspects of the application of the models to The Dalles Pool. The used to assign the bathymetry and boundary conditions are described in Appendix A. Summaries of the field data in the calibration and verification simulations are provided in Appendix B though Appendix D.

Hydrodynamics were verified using Spring 1996 and Summer 1997 Acoustic Doppler Current Profiler (ADCP) data. Dissolved gas and temperature verification used the Spring 1996, Summer 1996, and Summer 1997 pool study data.

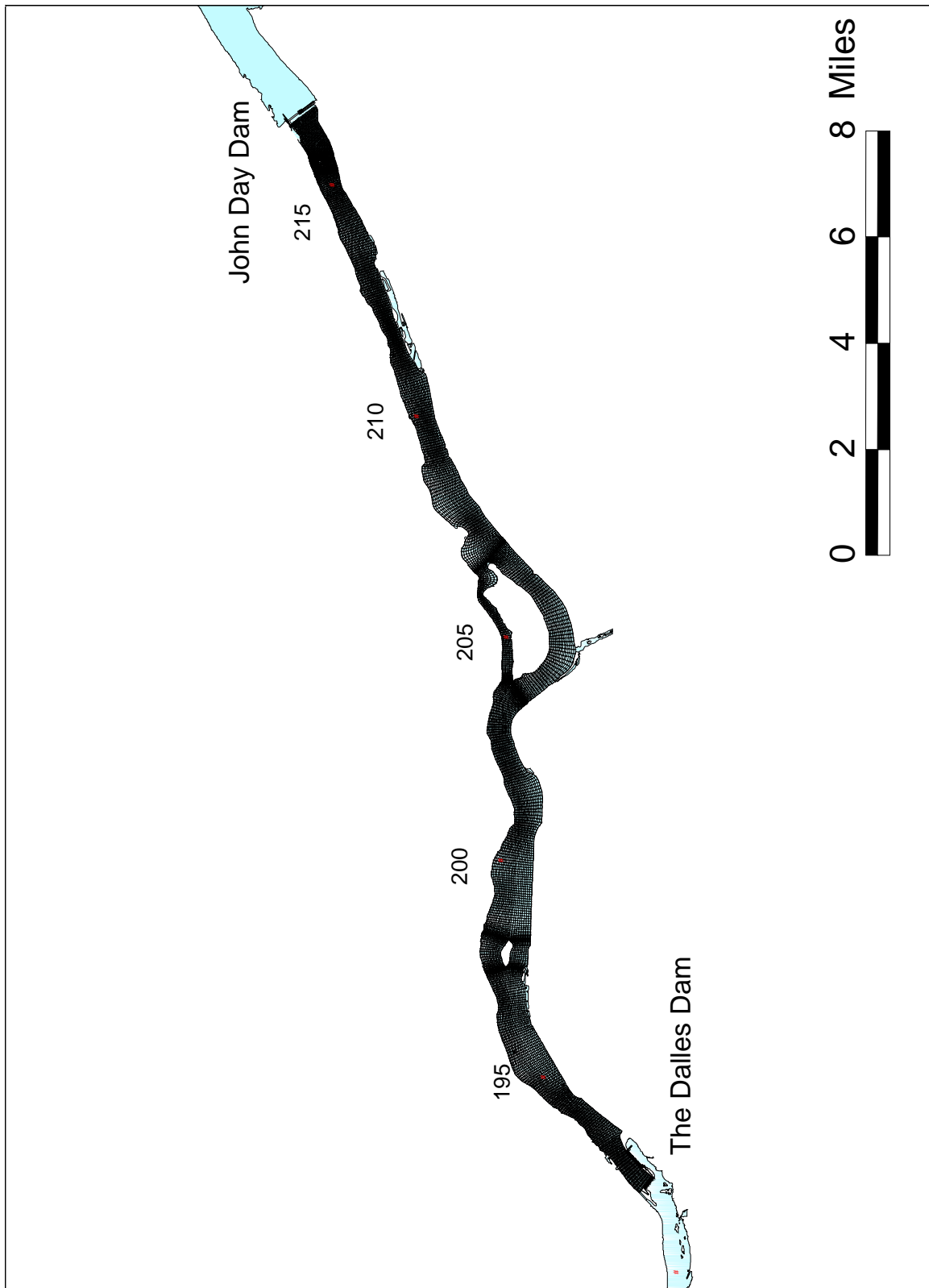
### **1.1 Model Grid**

The computational grid was generated using the Gridgen 9.1 code. Gridgen 9.1 is software for the generation of 3D, multiple block, structured grids. The code was developed for NASA Ames Research Center (Steinbrenner and Chawner, 1995).

To create the grid, a data file containing discrete geographical locations that outline the river shoreline was imported to Gridgen. In Gridgen, curves containing the data points

were created and joined to enclose 2-dimensional flow regions. Grid spacing was set in each flow region and the grids were smoothed using the Gridgen elliptic solver. The elliptic solver was used to minimize grid twist and skew. The flow regions were then joined end to end in the downstream direction to make up the entire flow domain and the entire 2-dimensional grid was written to file. Once the grid was created bottom elevations in each cell were assigned using the bathymetric data and procedure described in 0.

The model grid for The Dalles pool is shown in Figure 1. Larger scale maps of the model grid near the John Day dam and The Dalles dam boundaries are shown in Figure 2. Note that several small islands were not included in the model and these were replaced with bottom elevation approximately 2 ft below the low water surface elevation (the water is about 2 ft deep where the islands are).



**Figure 1. Model grid for The Dalles pool.**



**Figure 2. Model grid near John Day dam and The Dalles dam.**

## 1.2 Boundary Conditions

### 1.2.1 John Day Dam Sourcing Function

Spillway TDG concentrations were estimated using the John Day dam TDG sourcing function presented by Schnieder and Wilhelms (1997):

$$S_s = 108.5 + 2.03 \times 10^{-4} Q_s \quad (1)$$

where

$S_s$  = TDG saturation of spillway flow, percent; and

$Q_s$  = spillway flow, cfs.

Forebay temperatures and barometric pressures were used to compute concentration from the saturation estimated using equation (1).

## 1.3 Hydrodynamics Calibration and Verification

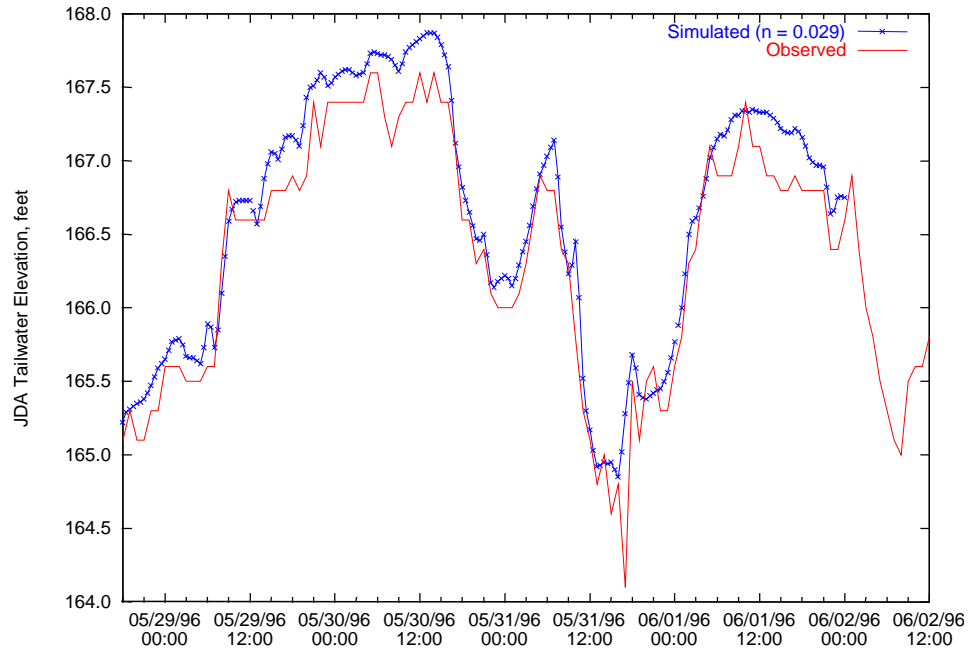
The model hydrodynamics were calibrated primarily using the John Day dam tailwater elevation gage. Due to instrumentation problems the coordinates of the ADCP data were subject to uncertain errors. Therefore, at this time, use of the ADCP data was restricted to qualitative comparisons with the model simulations.

In all simulations in this report a time step of 50 seconds was used. The simulations also used constant longitudinal and lateral turbulent eddy viscosities of 0.2 ft<sup>2</sup>/s.

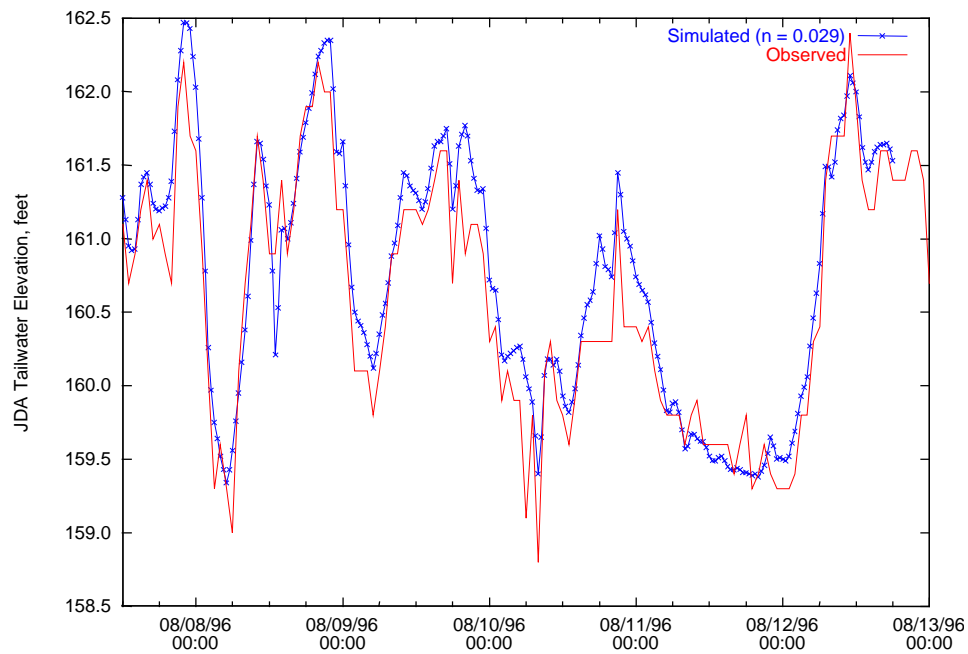
### 1.3.1 John Day Tailwater

The first step in the calibration procedure was to select a spatially uniform value of the Manning roughness coefficient that would yield computed water surface elevations in satisfactory agreement with the John Day dam tailwater gage. The Spring 1996 pool study period was selected because ADCP velocity measurements were also available for that period. Simulations were performed using Manning n values in the range of 0.026 to 0.030. Figure 3 compares the model simulation and measured tailwater elevation for a n-value of 0.029 which was chosen as the final parameter value to be used in the remainder of The Dalles Pool simulations.

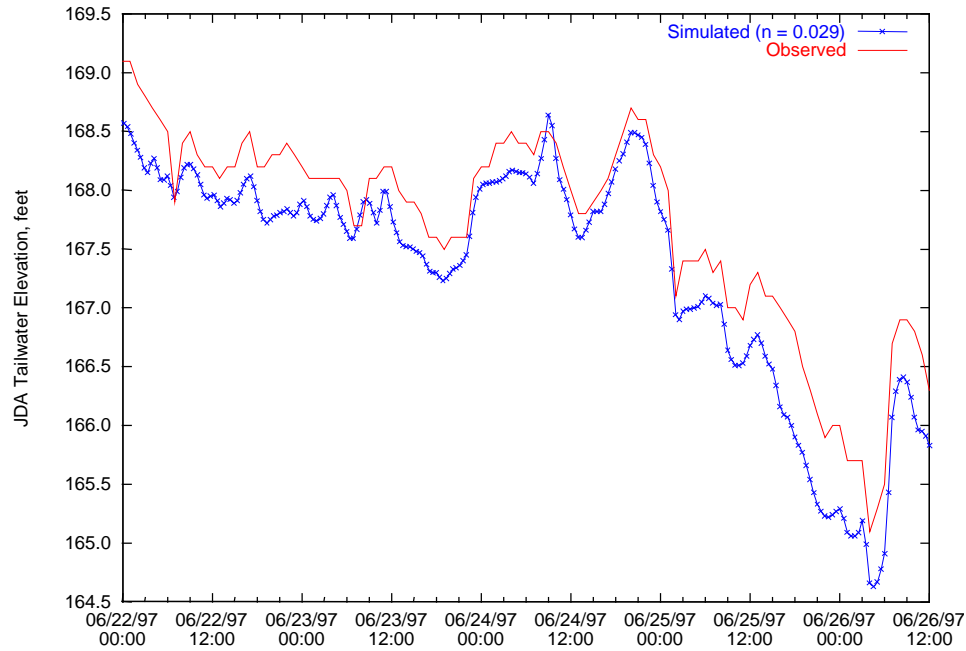
The selected n-value was verified for both the Summer 1996 and Summer 1997 pool study periods. The verification results are shown in Figure 4 and Figure 5.



**Figure 3. Comparison of simulated (Manning's  $n = 0.029$ ) and measured water surface elevation at the John Day dam tailwater gage during the Spring 1996 study period**



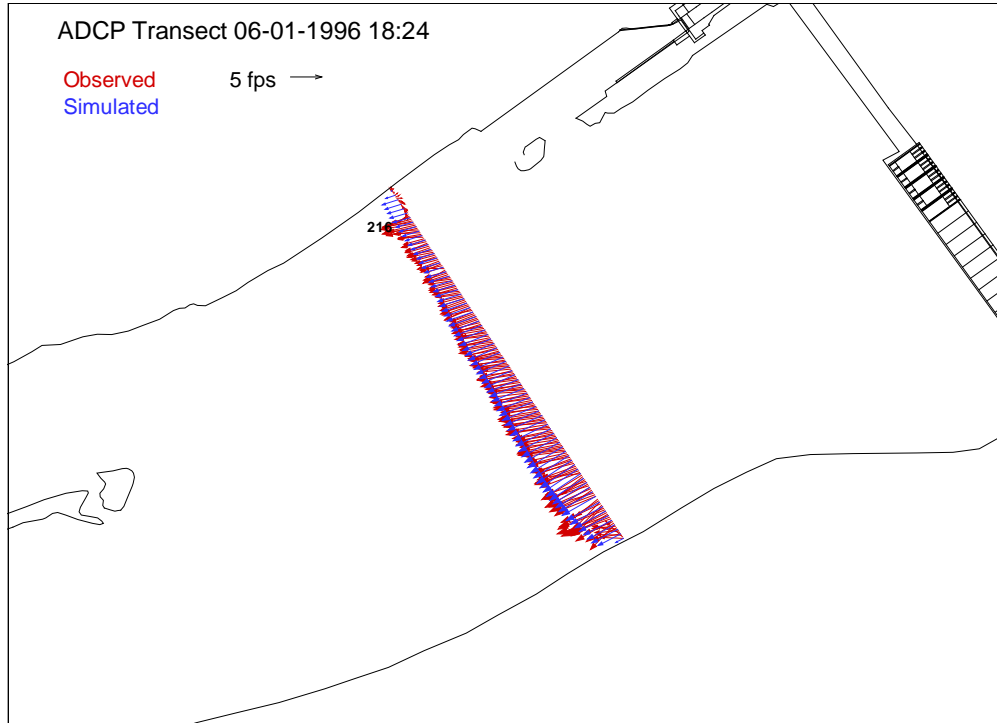
**Figure 4. Comparison of simulated (Manning's  $n = 0.029$ ) and measured water surface elevation at the John Day dam tailwater gage during the Summer 1996 study period**



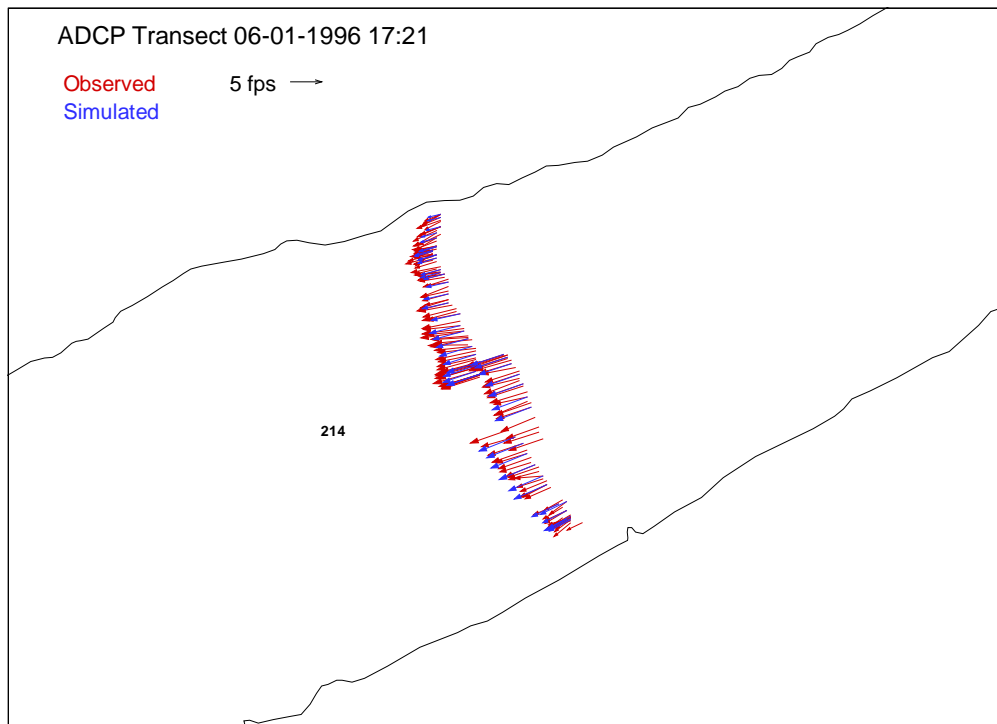
**Figure 5. Comparison of simulated (Manning's  $n = 0.029$ ) and measured water surface elevation at the John Day dam tailwater gage during the Summer 1997 study period**

### ***1.3.2 1996 ADCP Data***

Once the manning  $n$  value was selected, the model was run for the operational conditions that existed when the 1996 ADCP measurements were performed. The manning  $n$  value was not altered from the value of 0.029 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged 1996 ADCP data in Figure 6 through Figure 14.

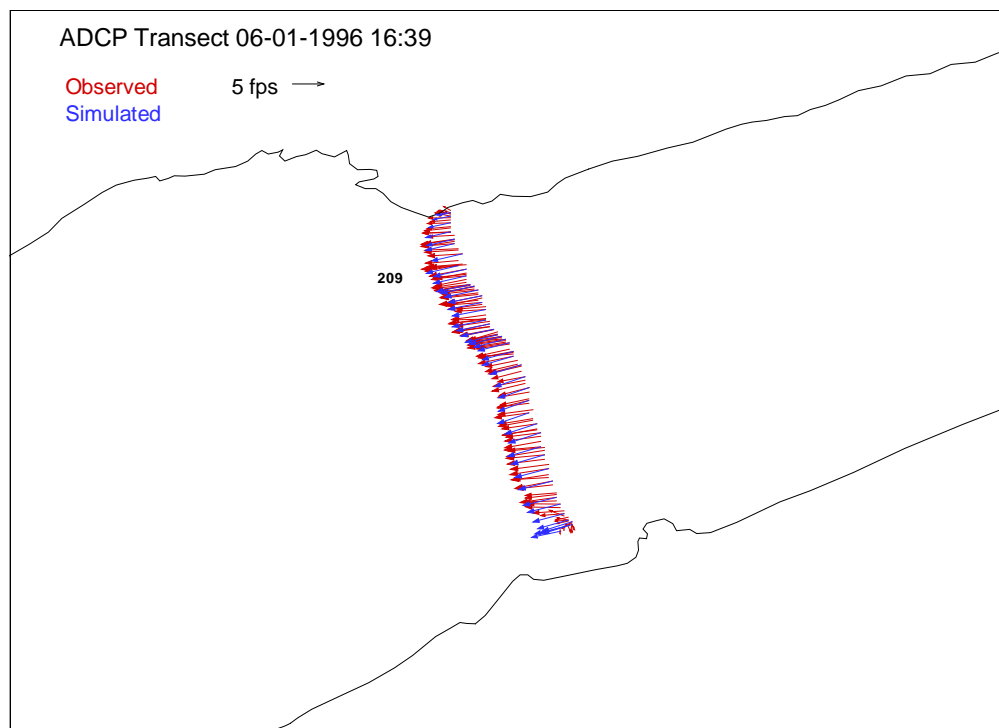


**Figure 6. Simulated and observed depth-averaged velocities near John Day dam on June 1, 1996.**

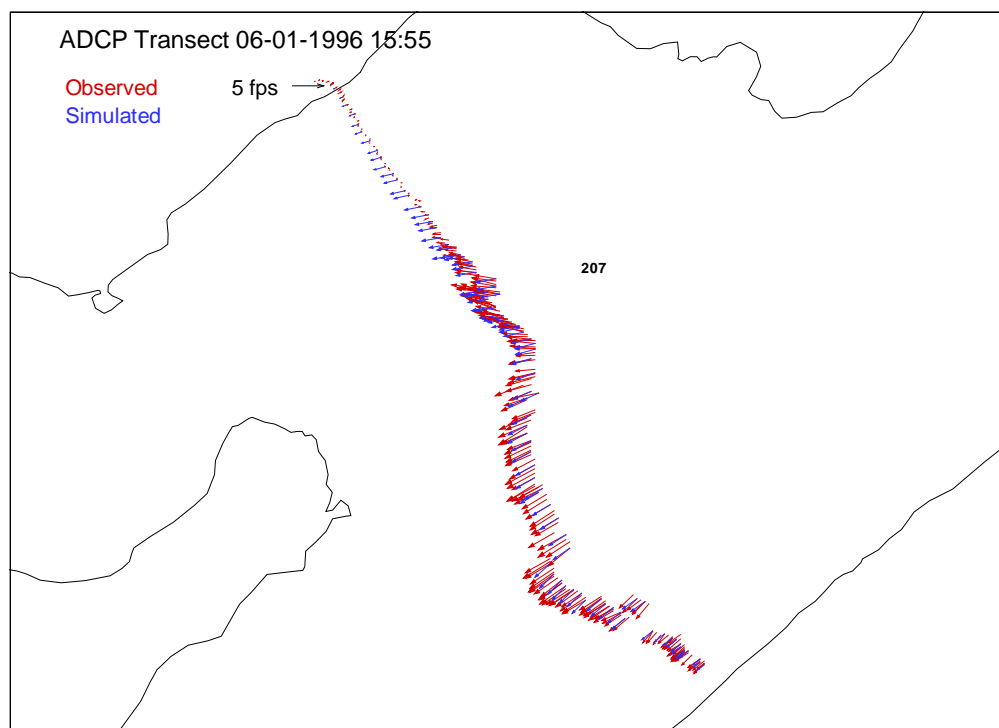


**Figure 7. Simulated and observed depth-averaged velocities below John Day dam on June 1, 1996.**

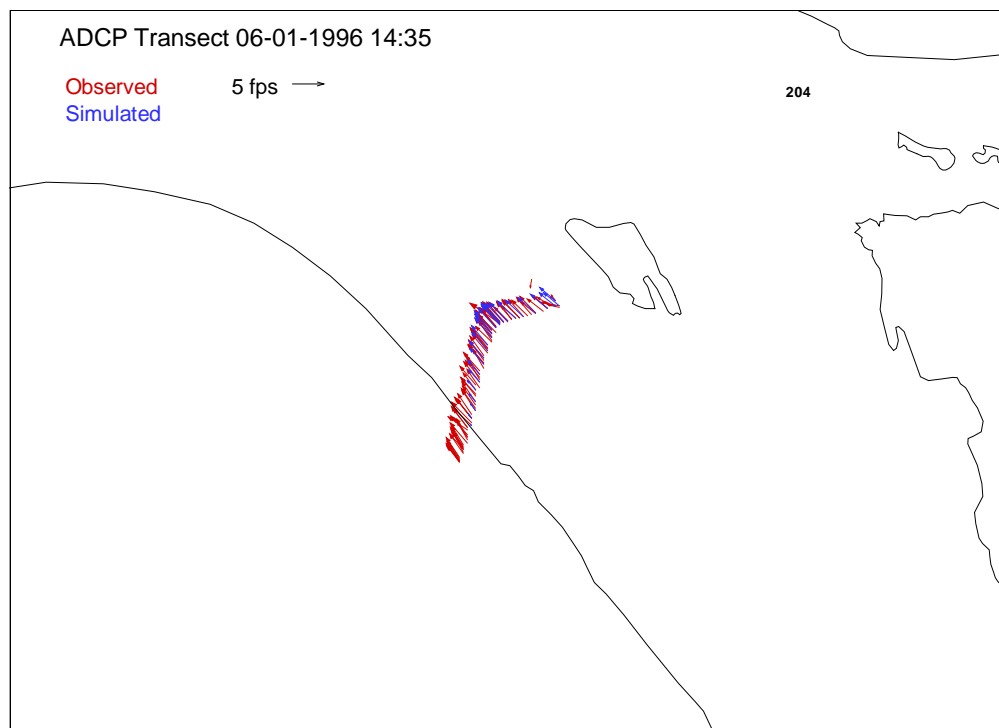




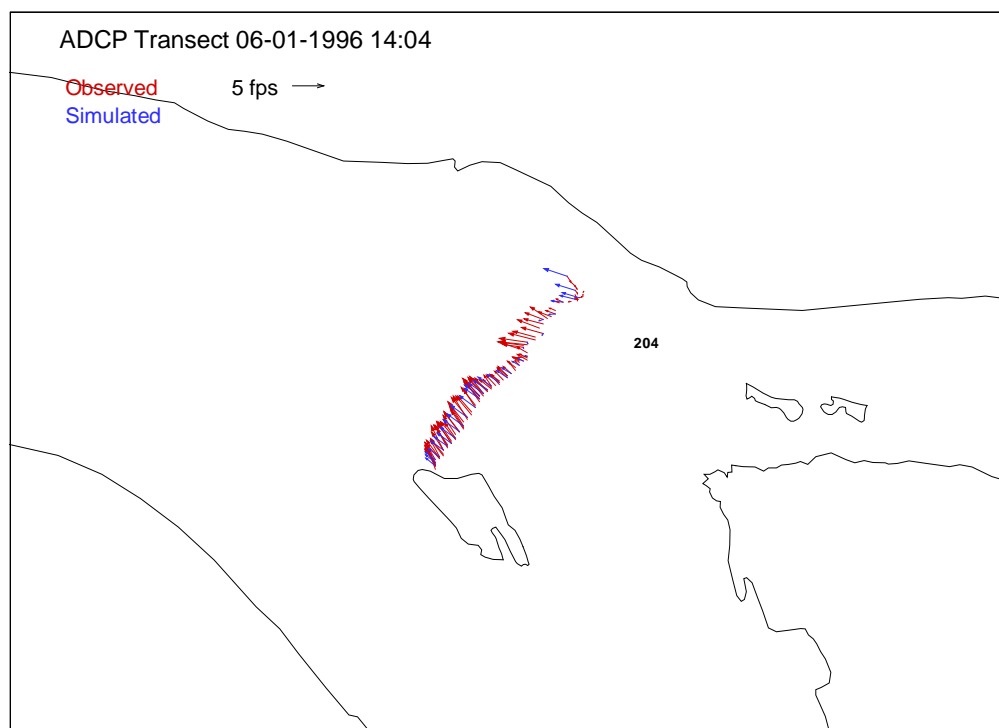
**Figure 8. Simulated and observed depth-averaged velocities near river mile 209 on June 1, 1996.**



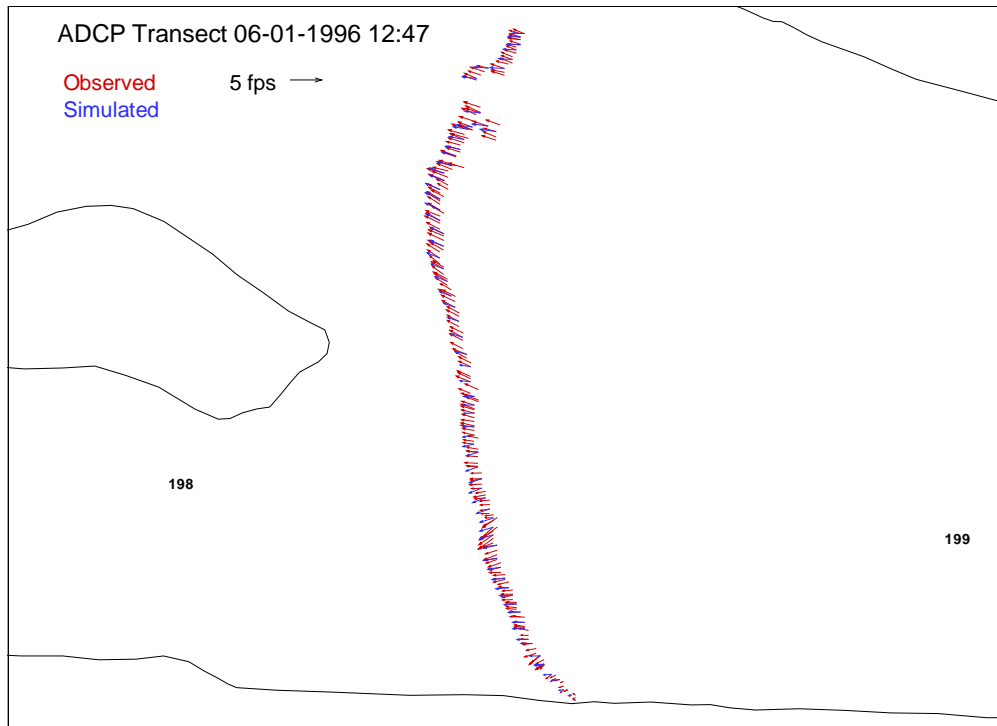
**Figure 9. Simulated and observed depth-averaged velocities above Miller Island on June 1, 1996.**



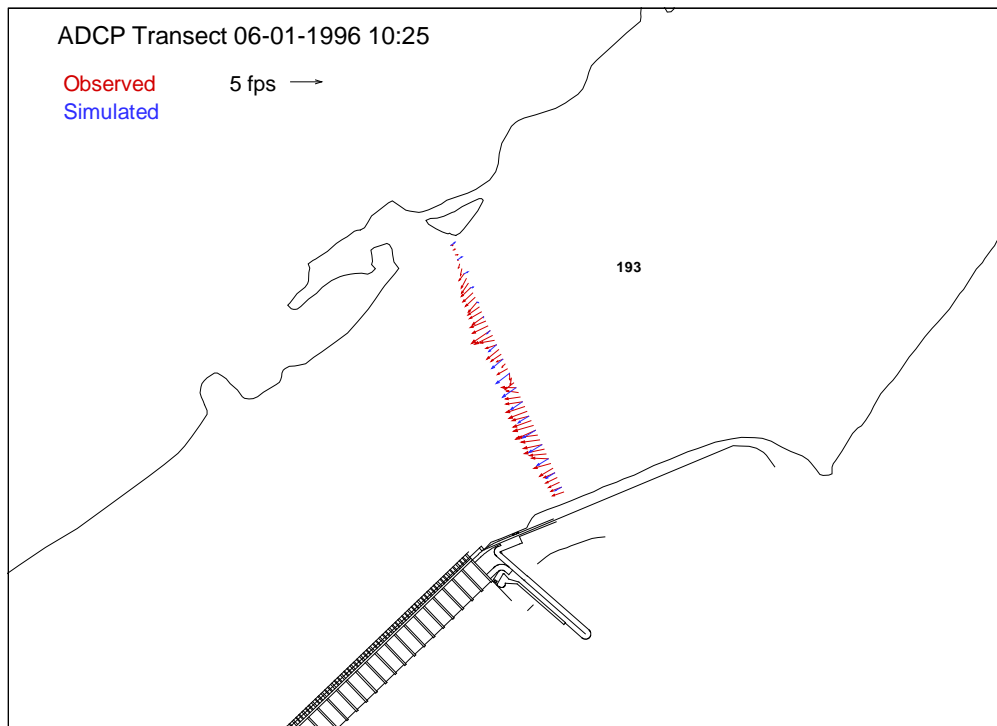
**Figure 10. Simulated and observed depth-averaged velocities near Miller Island on June 1, 1996.**



**Figure 11. Simulated and observed depth-averaged velocities near Miller Island on June 1, 1996.**



**Figure 12. Simulated and observed depth-averaged velocities near York Island on June 1, 1996.**



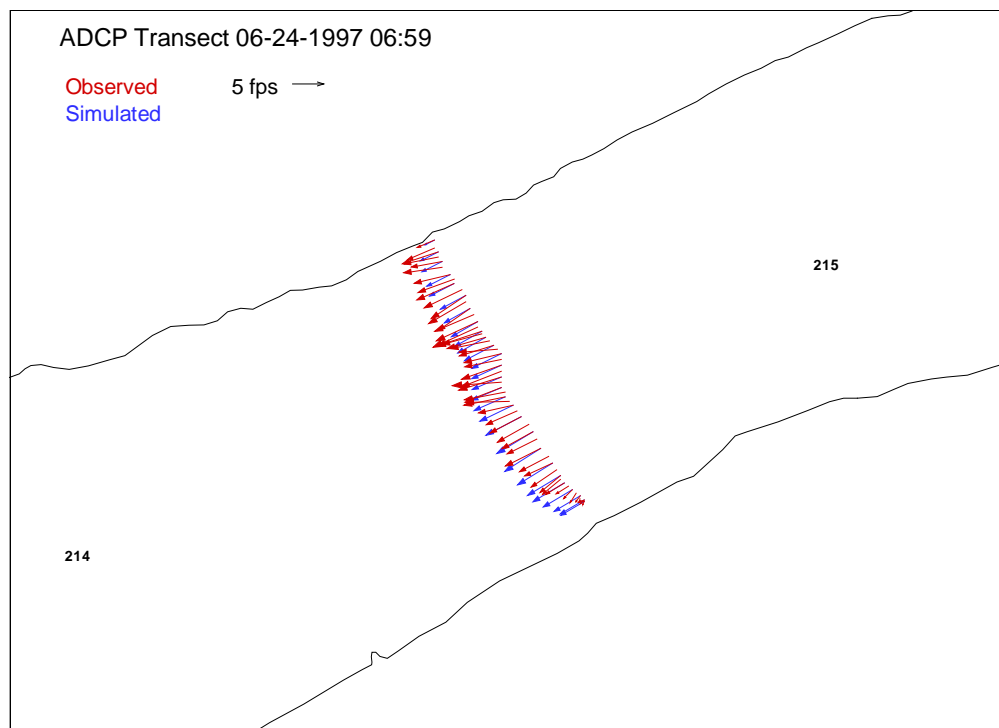
**Figure 13. Simulated and observed depth-averaged velocities near The Dalles Dam on June 1, 1996.**



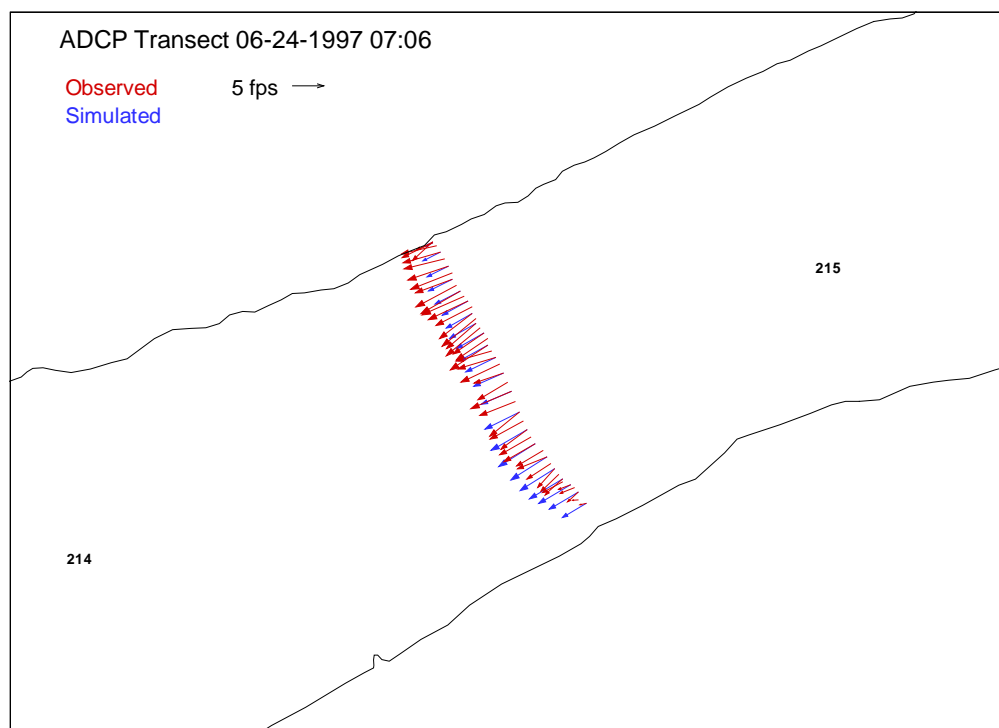
**Figure 14. Simulated and observed depth-averaged velocities near The Dalles Dam on 6/1/96.**

### ***1.3.3 1997 ADCP Data***

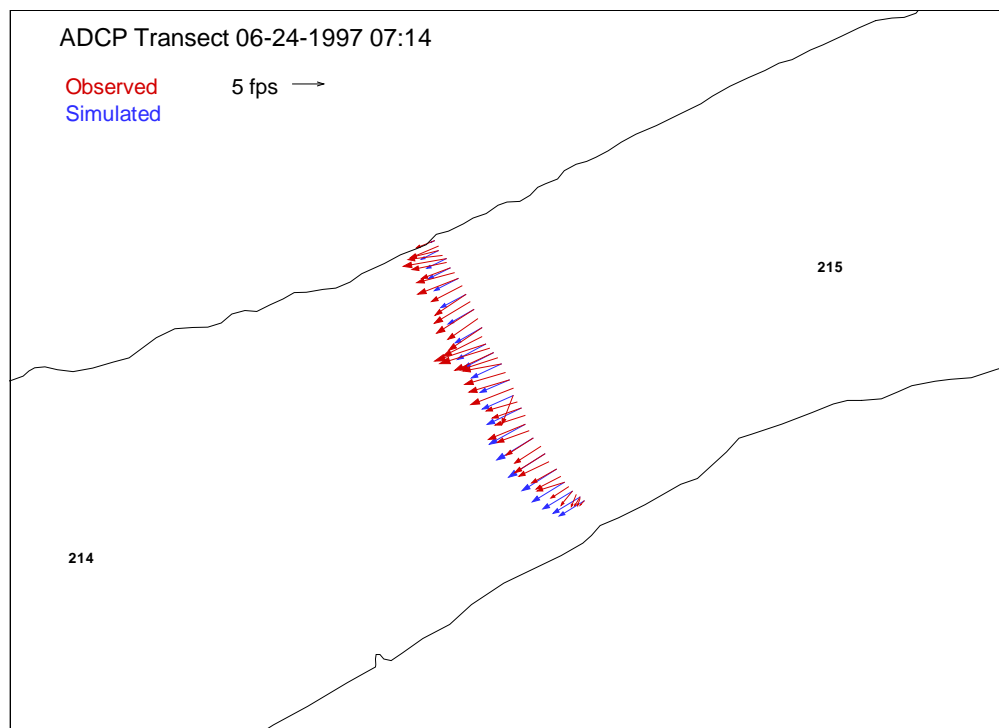
As was the case for the 1996 ADCP case, the model was run using operational conditions that existed when the 1997 ADCP measurements were performed. Again, the Manning  $n$  value was not altered from the value of 0.029 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged 1997 ADCP data in Figure 15 through Figure 40.



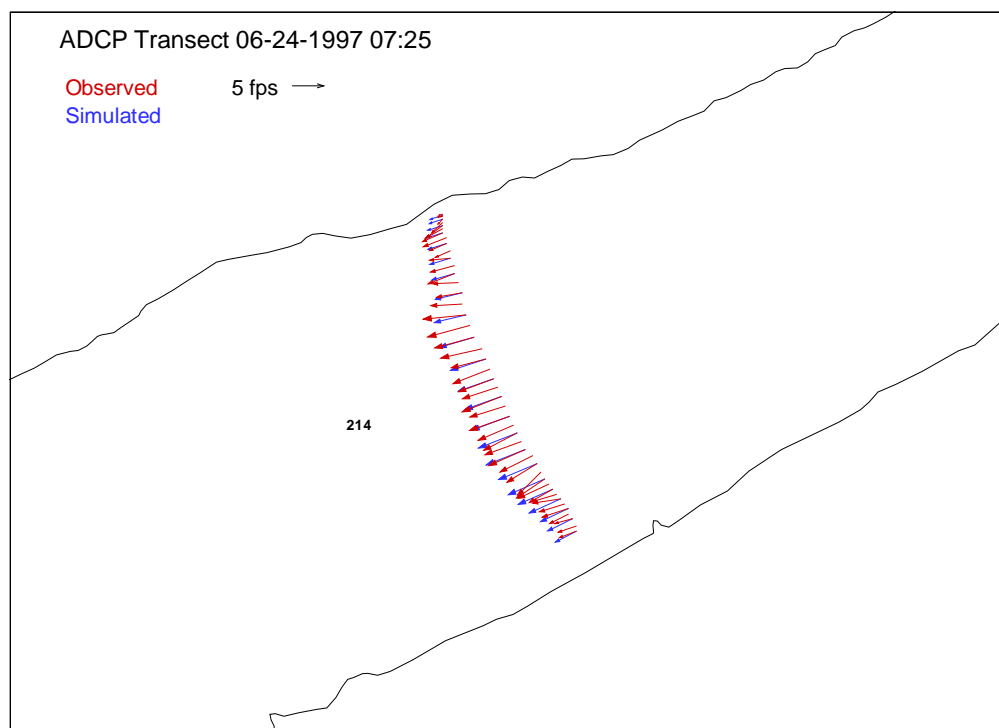
**Figure 15. Simulated and observed depth-averaged velocities near river mile 214 on June 24, 1997.**



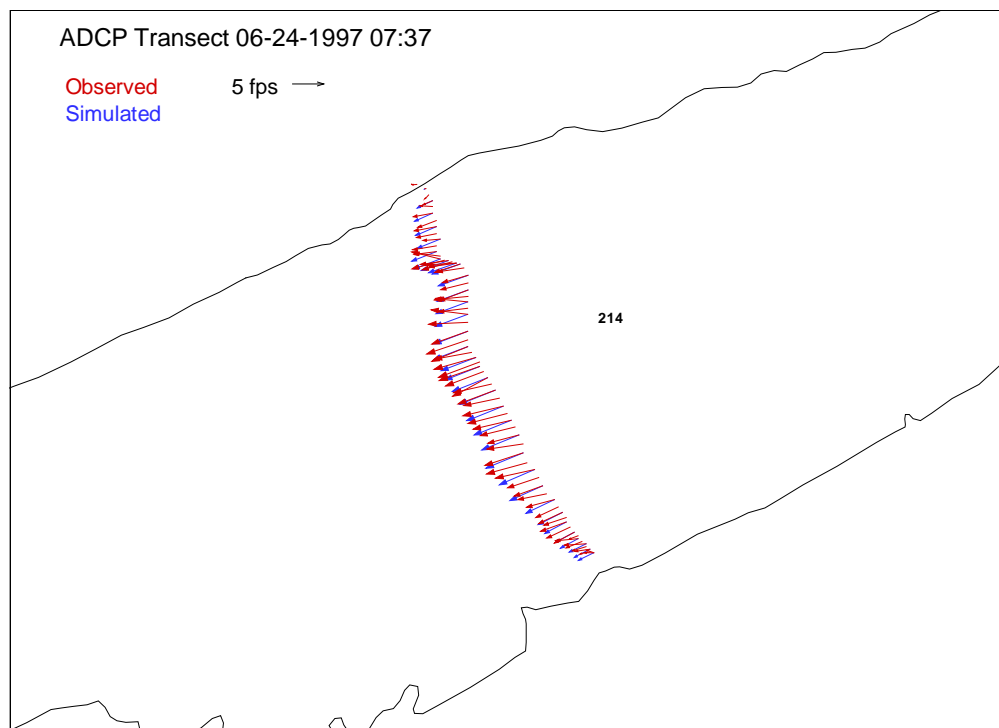
**Figure 16. Simulated and observed depth-averaged velocities near river mile 214 on June 24, 1997.**



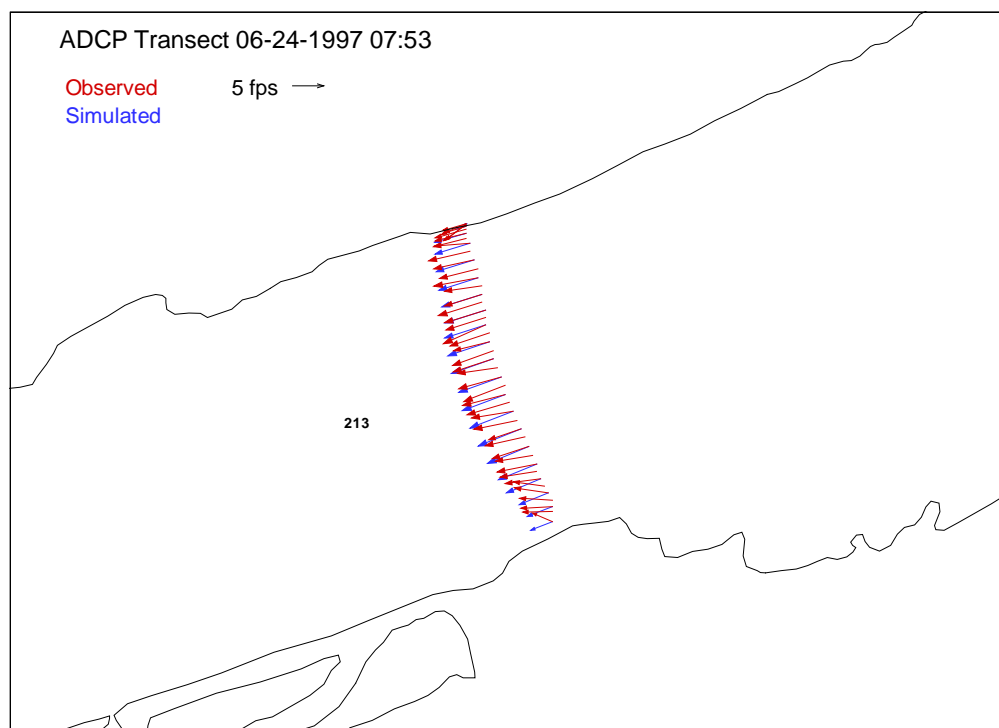
**Figure 17. Simulated and observed depth-averaged velocities near river mile 214 on June 24, 1997.**



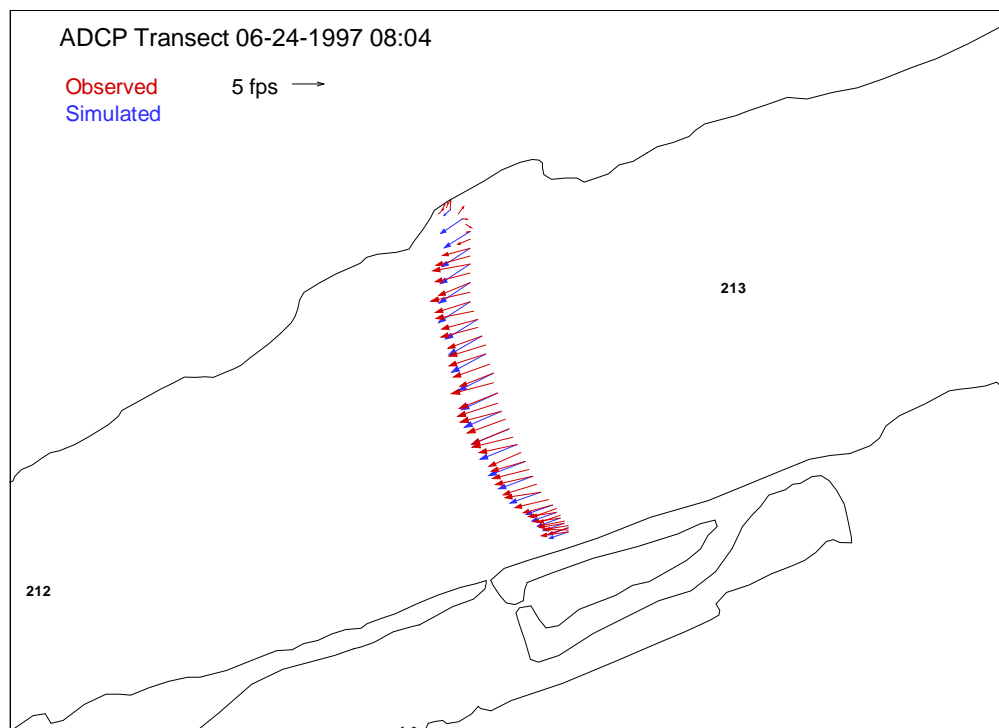
**Figure 18. Simulated and observed depth-averaged velocities near river mile 214 on June 24, 1997.**



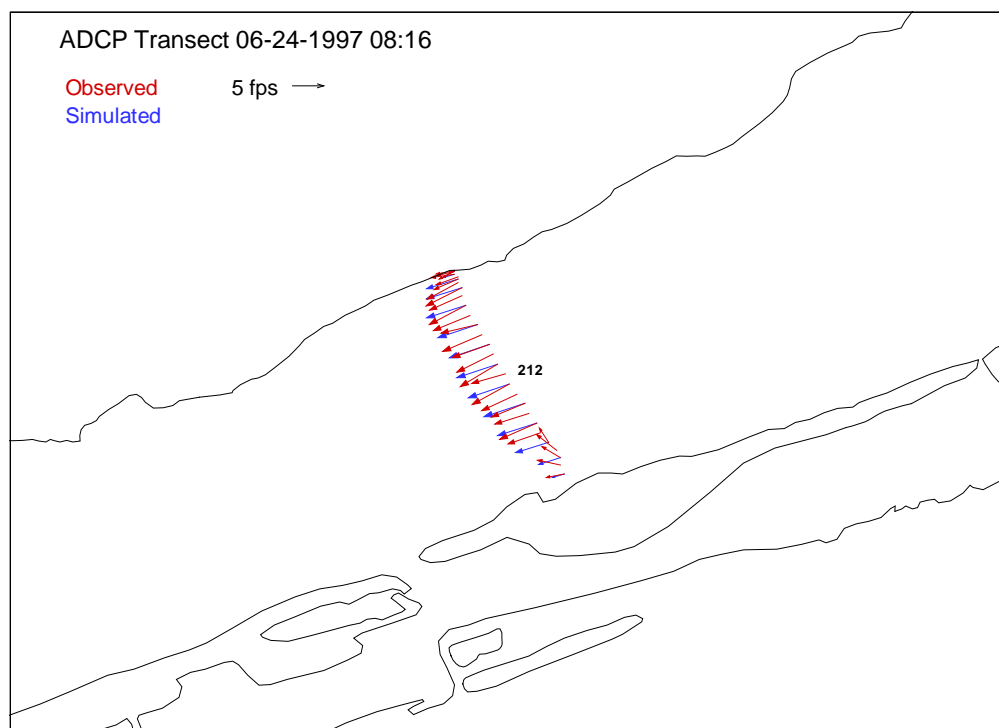
**Figure 19. Simulated and observed depth-averaged velocities near river mile 214 on June 24, 1997.**



**Figure 20. Simulated and observed depth-averaged velocities near river mile 213 on June 24, 1997.**

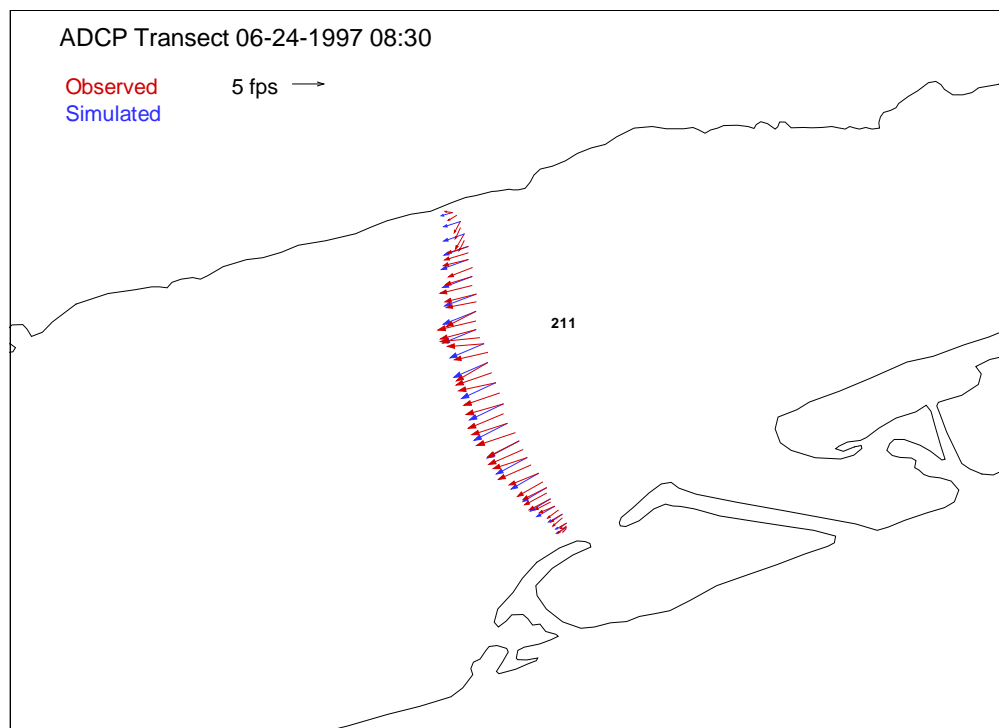


**Figure 21. Simulated and observed depth-averaged velocities near river mile 213 on June 24, 1997.**

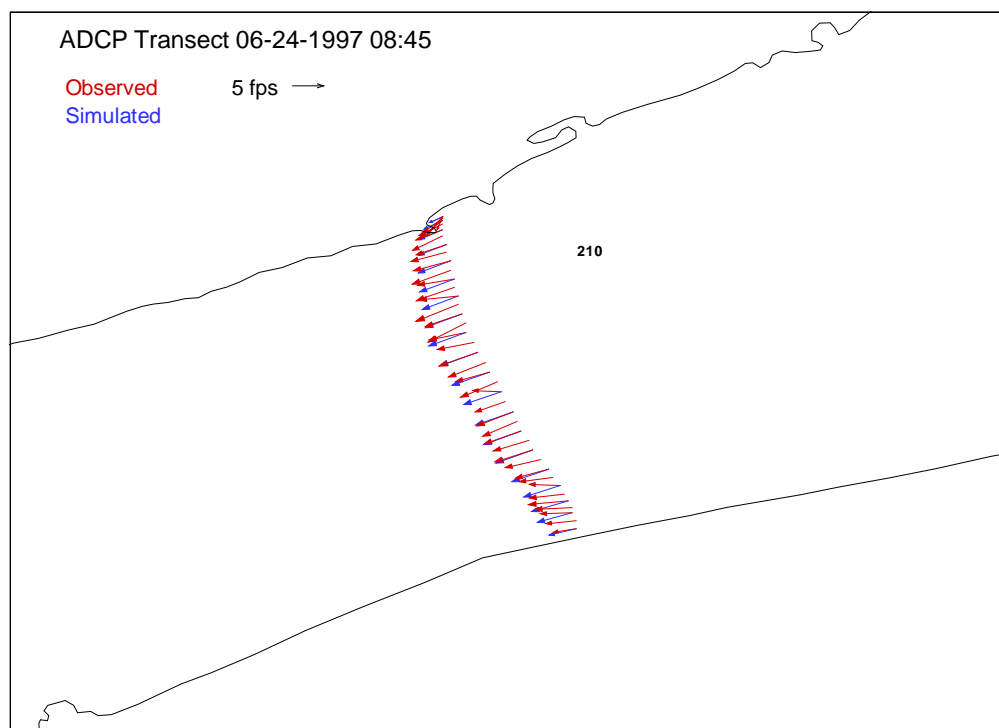


**Figure 22. Simulated and observed depth-averaged velocities near river mile 212 on June 24, 1997.**

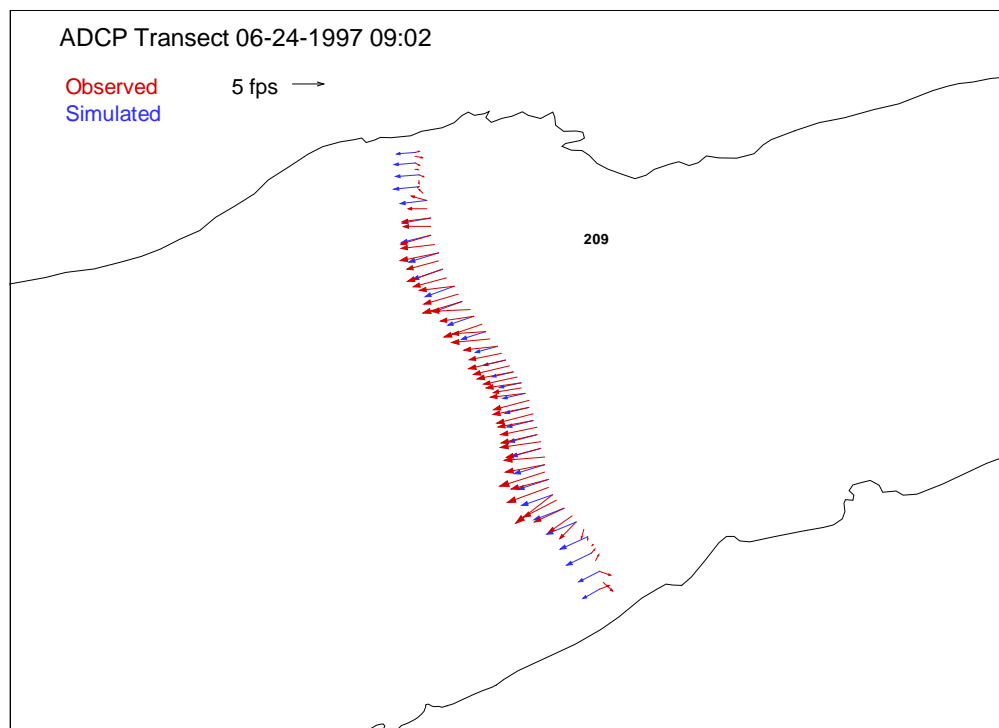




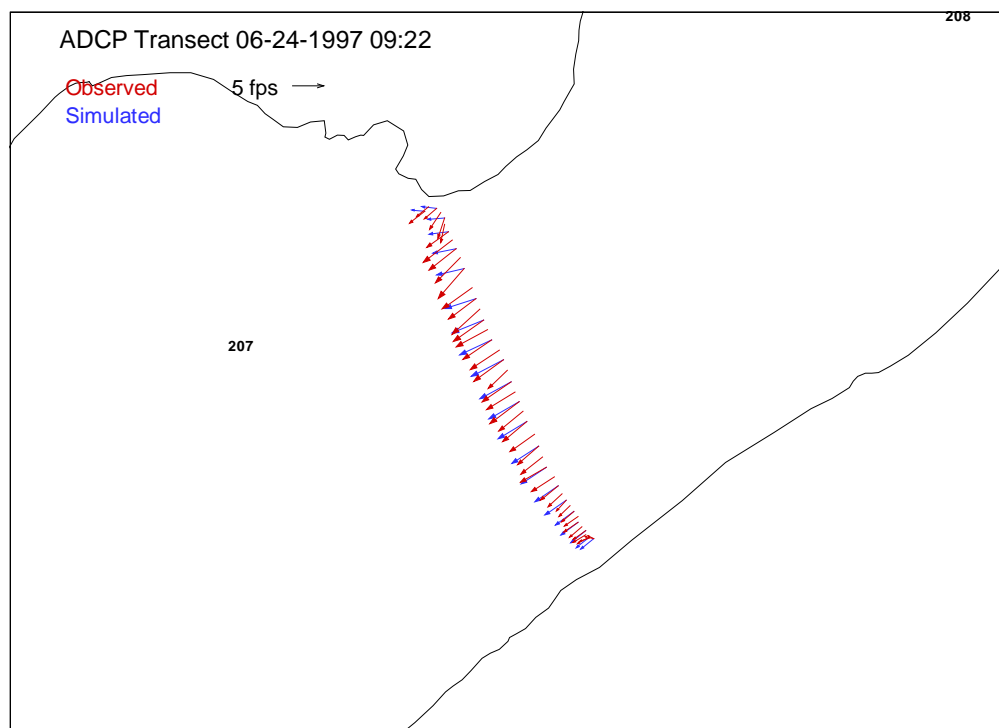
**Figure 23. Simulated and observed depth-averaged velocities near river mile 211 on June 24, 1997.**



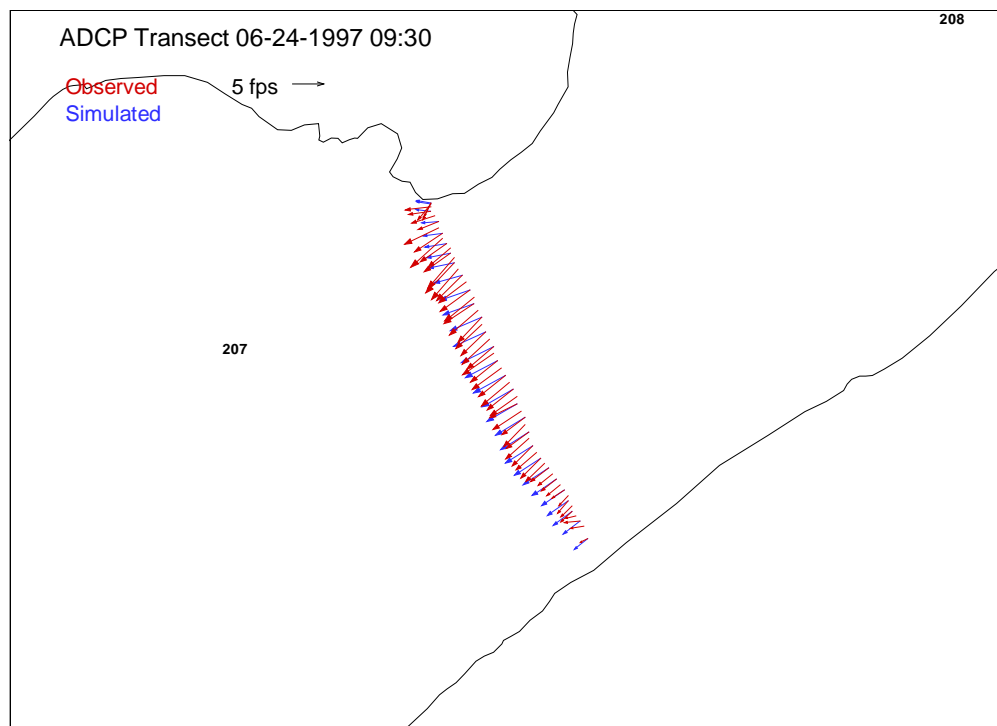
**Figure 24. Simulated and observed depth-averaged velocities near river mile 210 on June 24, 1997.**



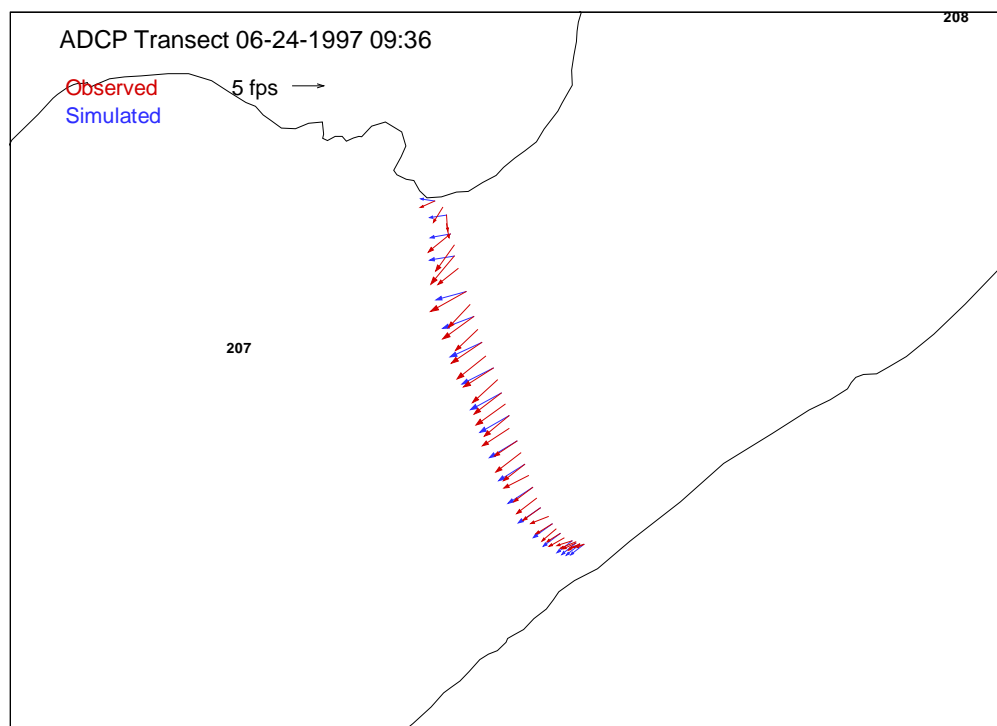
**Figure 25. Simulated and observed depth-averaged velocities near river mile 209 on June 24, 1997.**



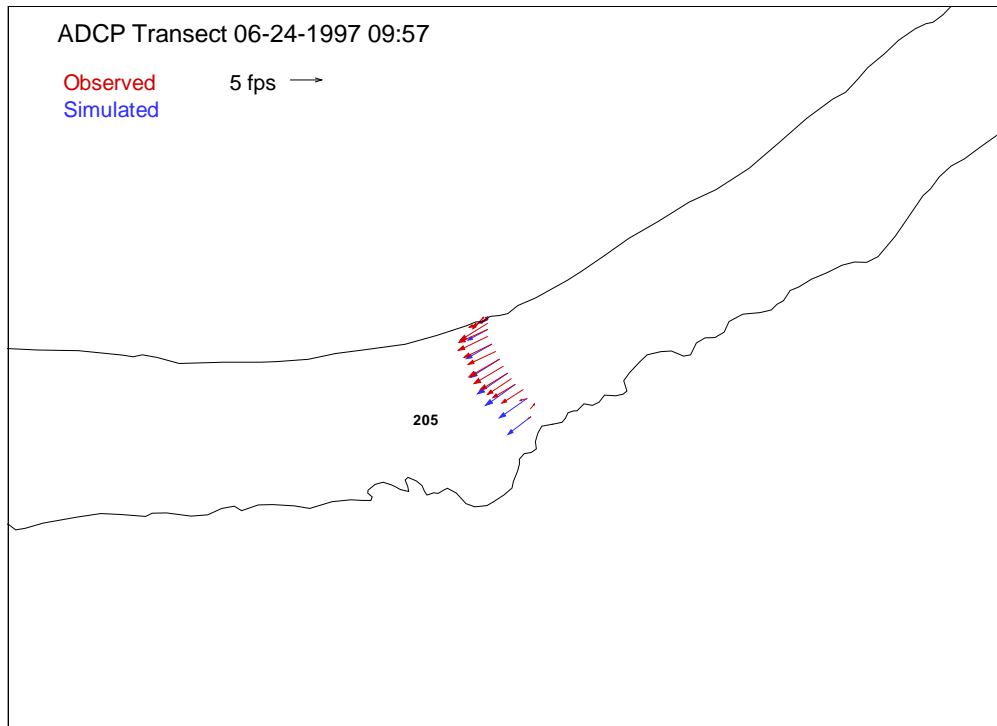
**Figure 26. Simulated and observed depth-averaged velocities near river mile 207 on June 24, 1997.**



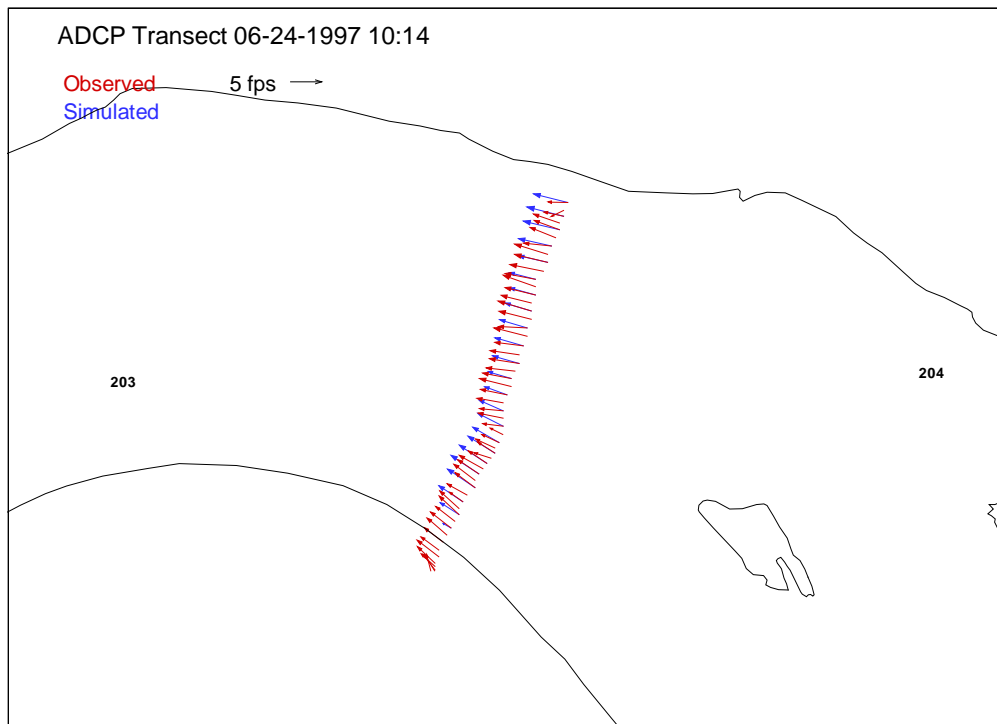
**Figure 27. Simulated and observed depth-averaged velocities near river mile 207 on June 24, 1997.**



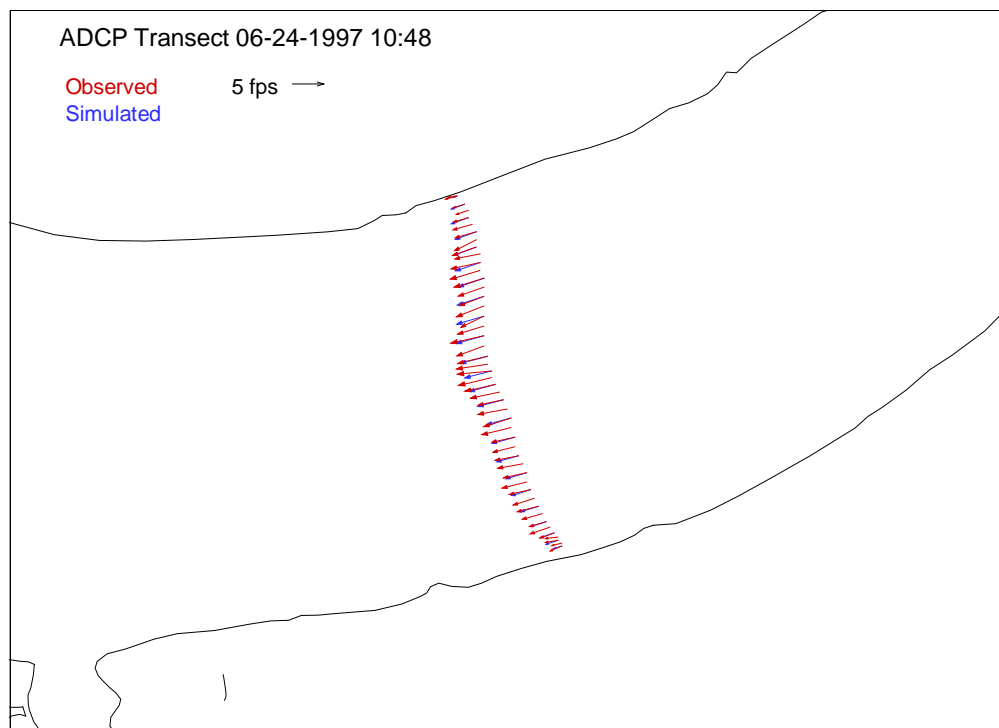
**Figure 28. Simulated and observed depth-averaged velocities near river mile 207 on June 24, 1997.**



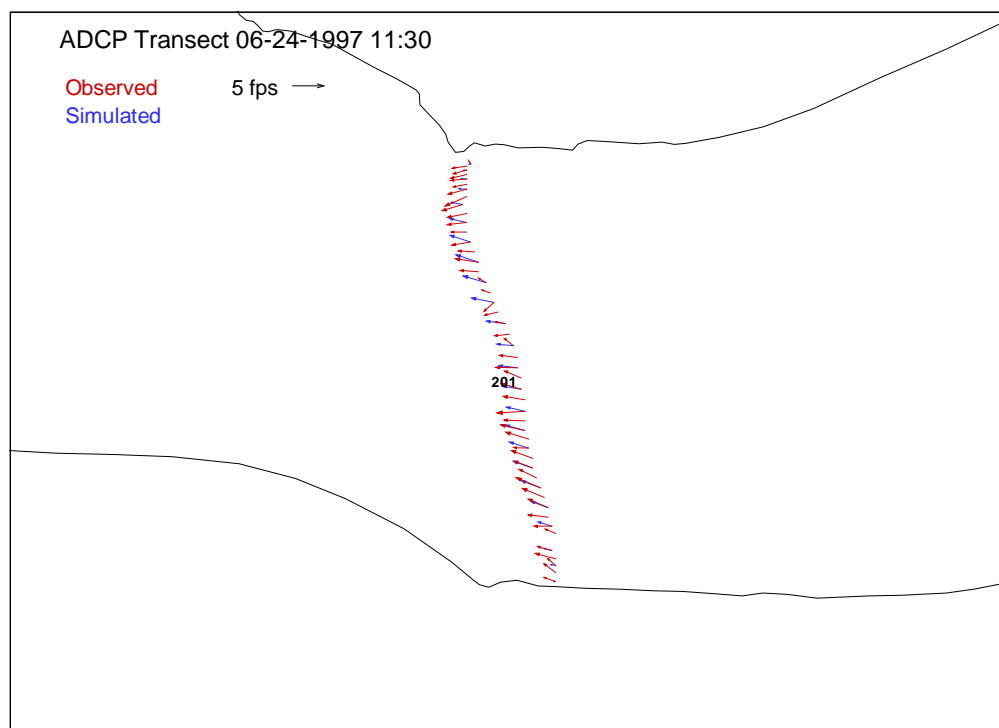
**Figure 29. Simulated and observed depth-averaged velocities near river mile 205 on June 24, 1997.**



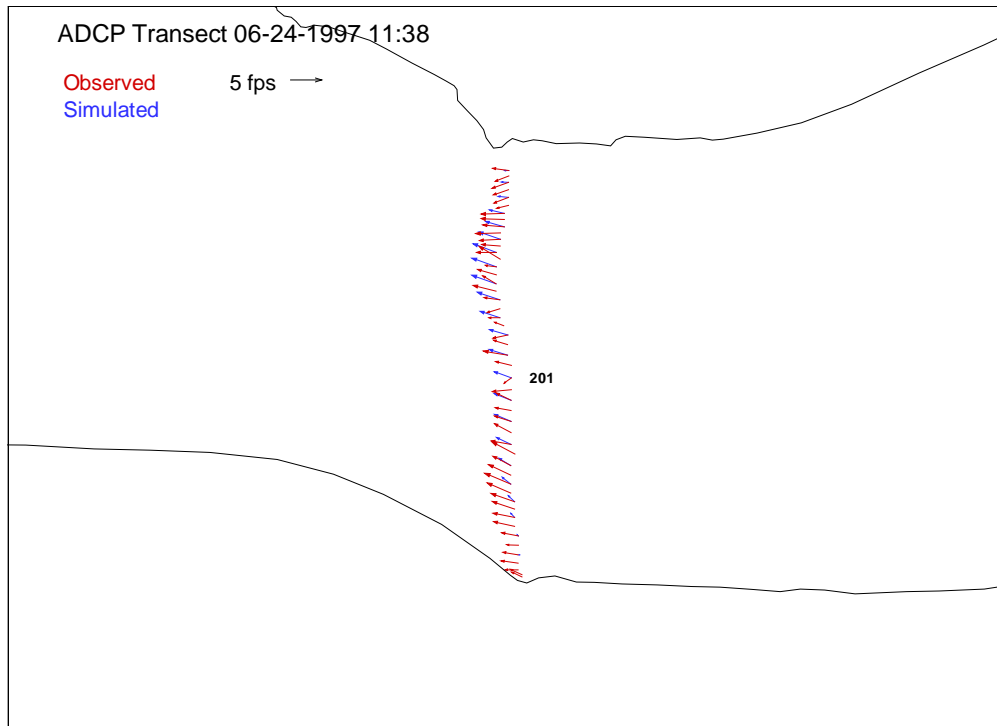
**Figure 30. Simulated and observed depth-averaged velocities near river mile 203 on June 24, 1997.**



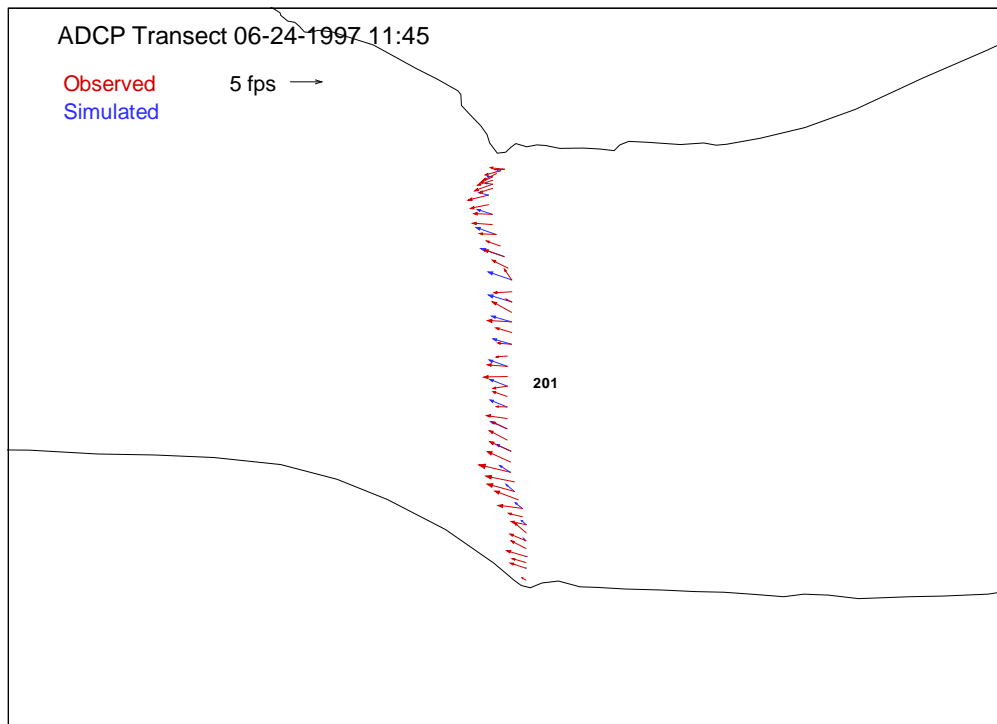
**Figure 31. Simulated and observed depth-averaged velocities near Miller Island on June 24, 1997.**



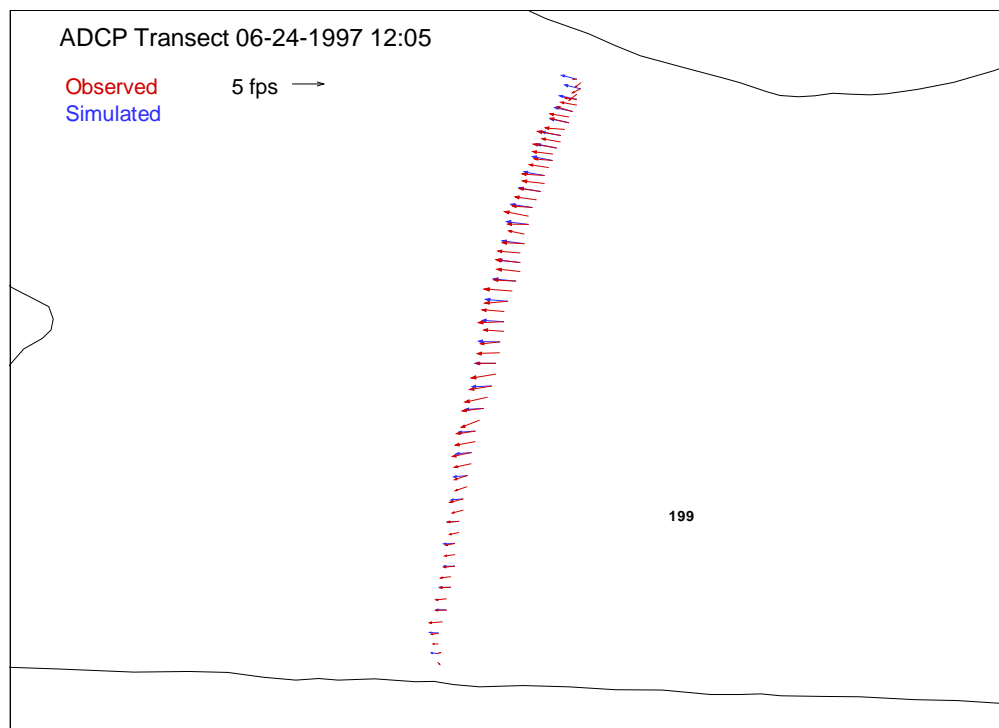
**Figure 32. Simulated and observed depth-averaged velocities near river mile 201 on June 24, 1997.**



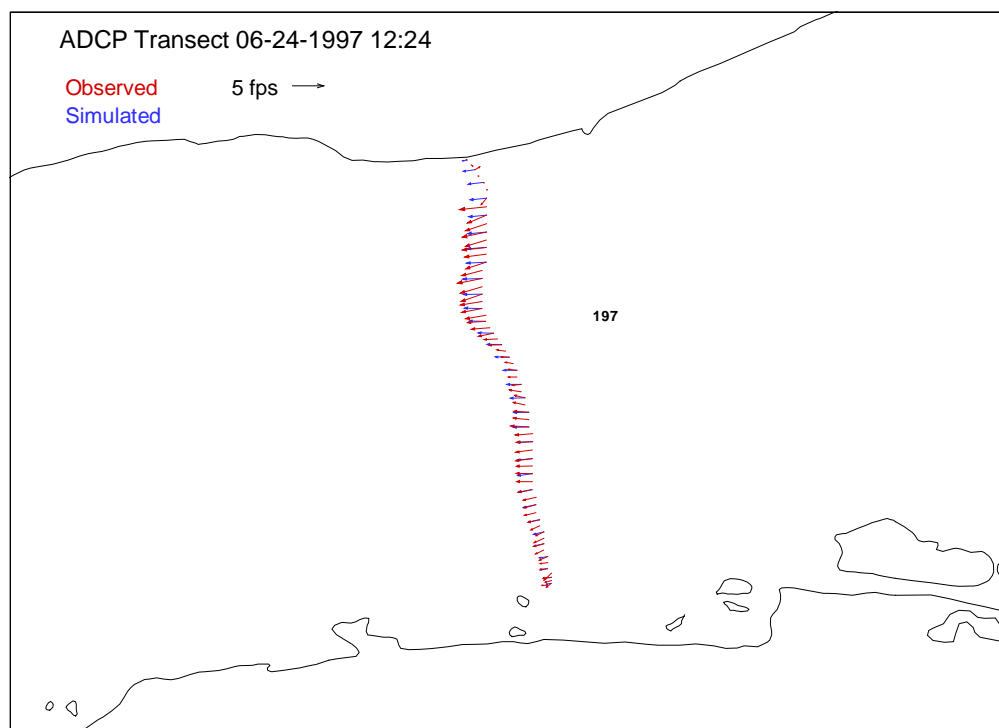
**Figure 33. Simulated and observed depth-averaged velocities near river mile 201 on June 24, 1997.**



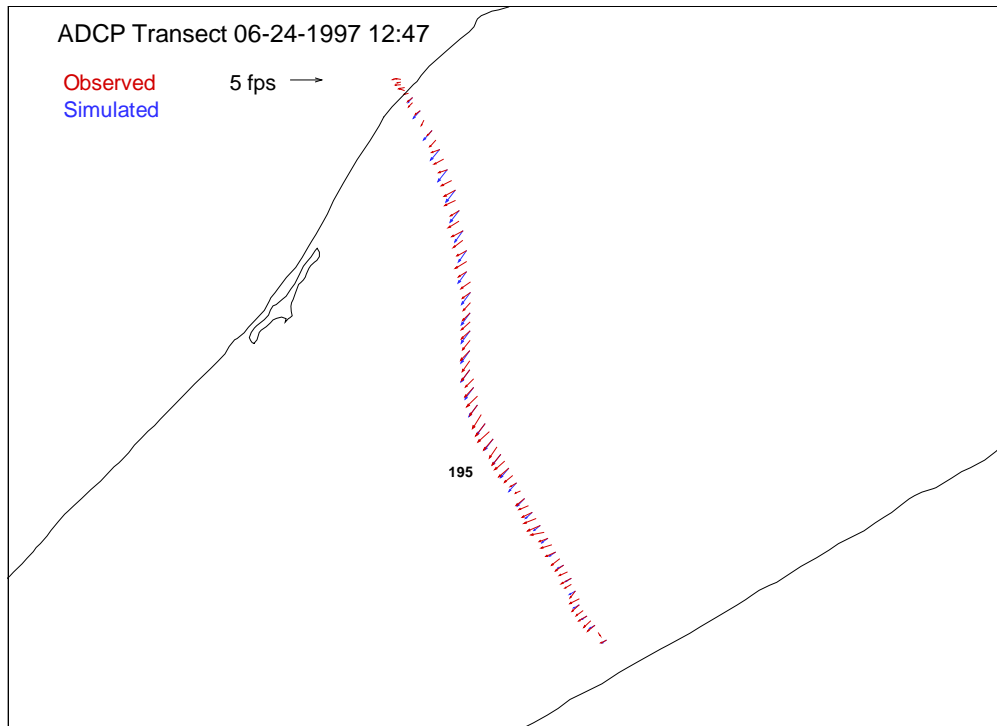
**Figure 34. Simulated and observed depth-averaged velocities near river mile 201 on June 24, 1997.**



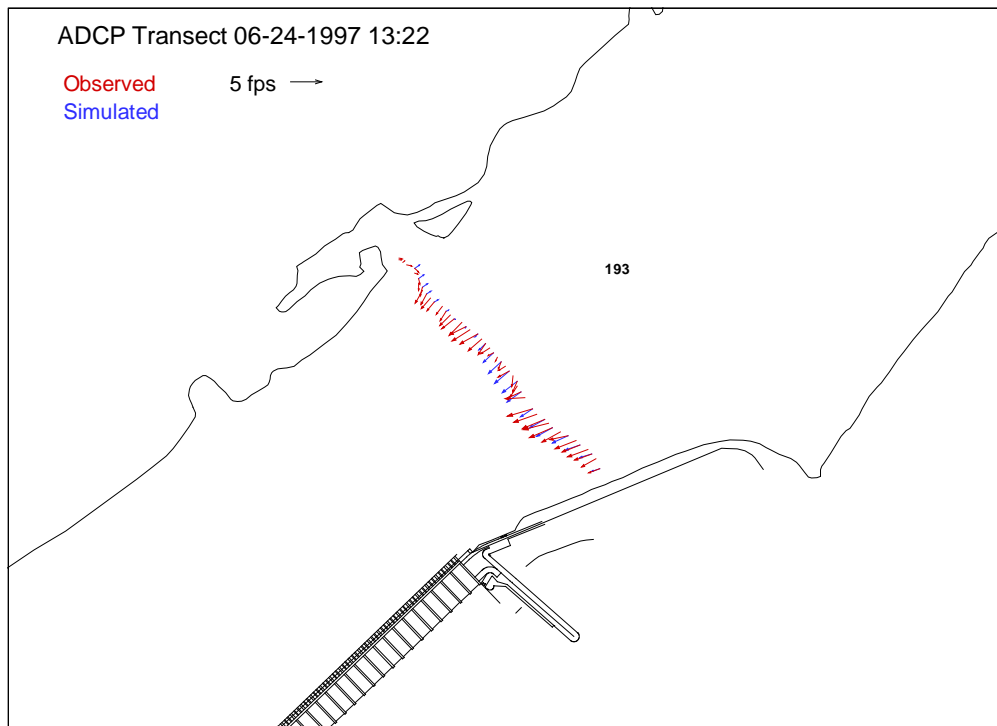
**Figure 35. Simulated and observed depth-averaged velocities near river mile 199 on June 24, 1997.**



**Figure 36. Simulated and observed depth-averaged velocities near river mile 197 on June 24, 1997.**

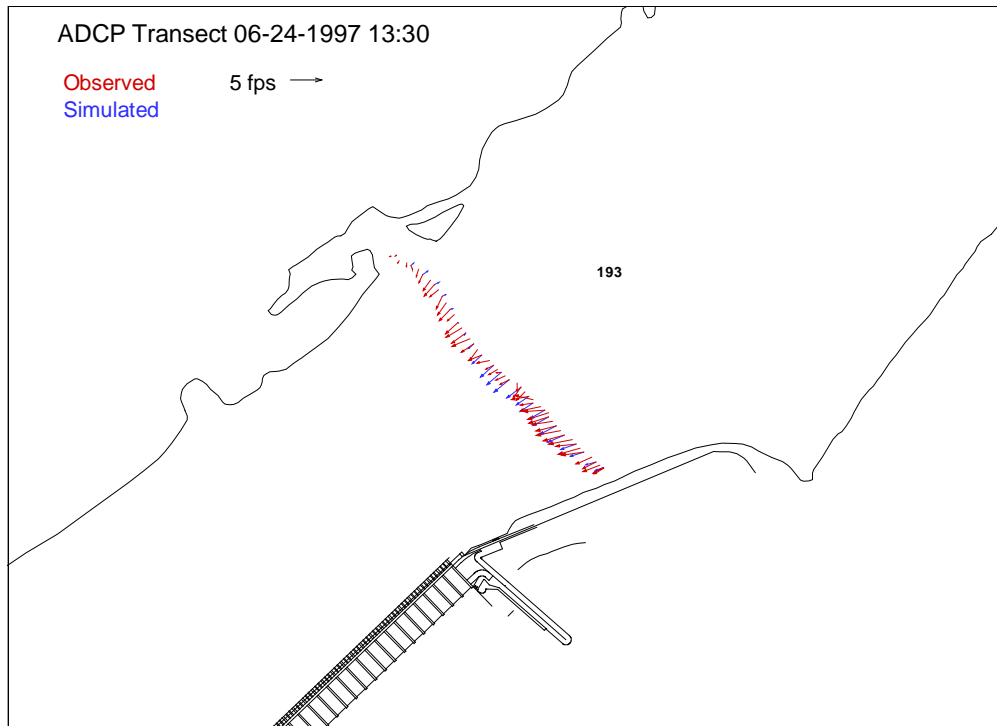


**Figure 37. Simulated and observed depth-averaged velocities near river mile 196 on June 24, 1997.**

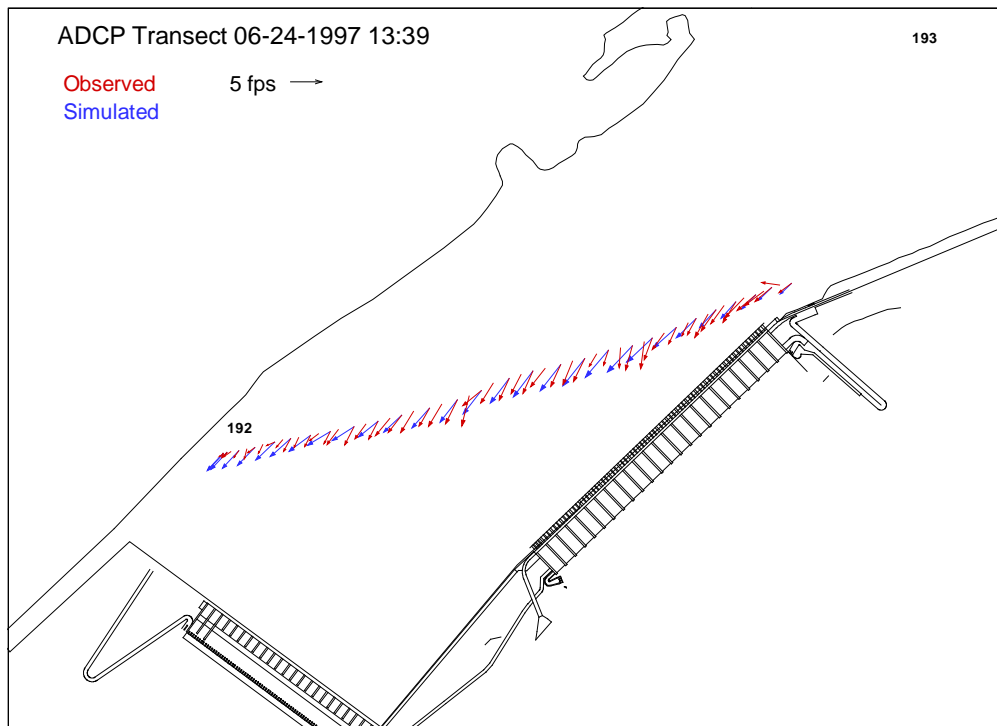


**Figure 38. Simulated and observed depth-averaged velocities near The Dalles dam on June 24, 1997.**



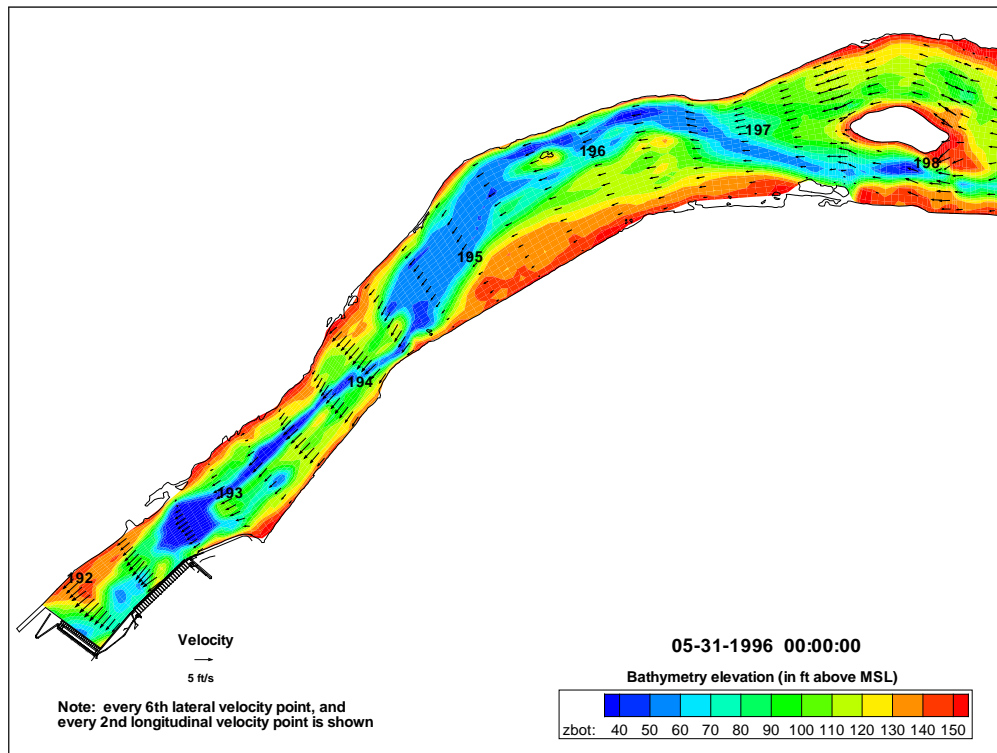


**Figure 39. Simulated and observed depth-averaged velocities near The Dalles dam on June 24, 1997.**



**Figure 40. Simulated and observed depth-averaged velocities near The Dalles dam on June 24, 1997.**

### 1.3.4 Simulated spatial velocity distribution during the Spring 1996 study.



**Figure 41. Spatial velocity distribution during the Spring 1996 study period.**

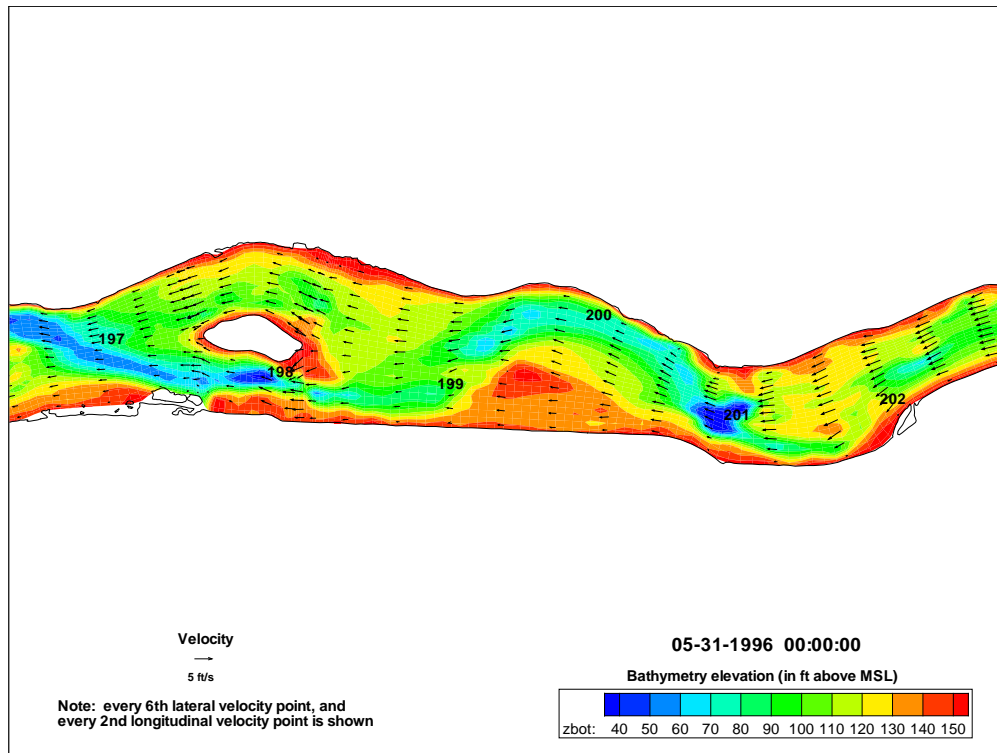


Figure 42. Spatial velocity distribution during the Spring 1996 study period.

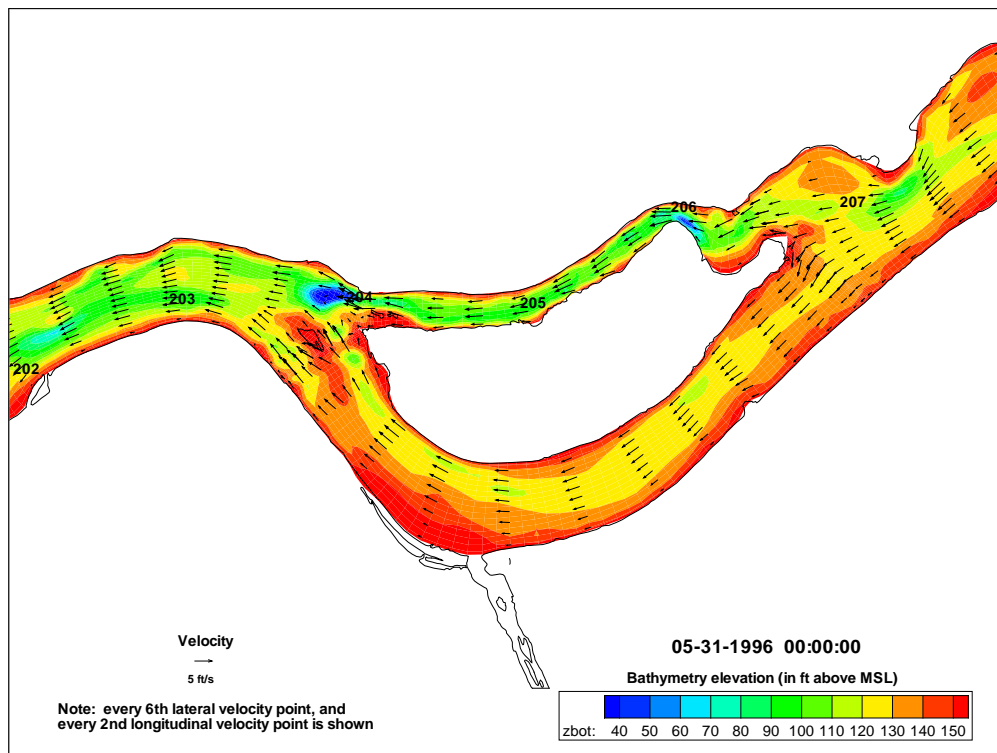


Figure 43. Spatial velocity distribution during the Spring 1996 study period.

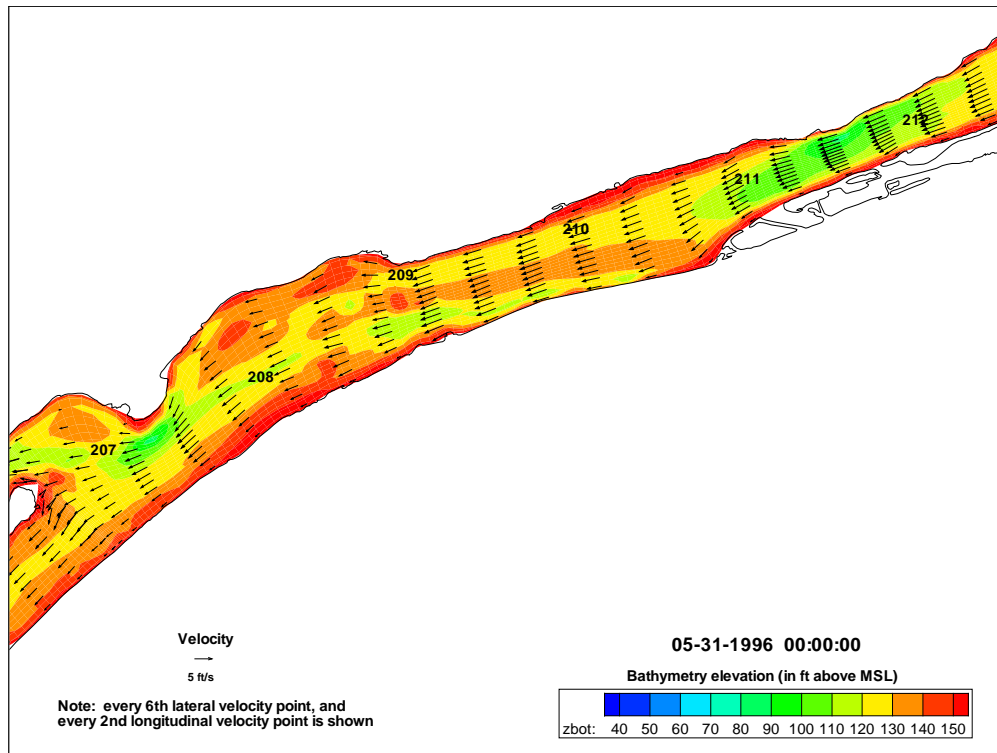


Figure 44. Spatial velocity distribution during the Spring 1996 study period.

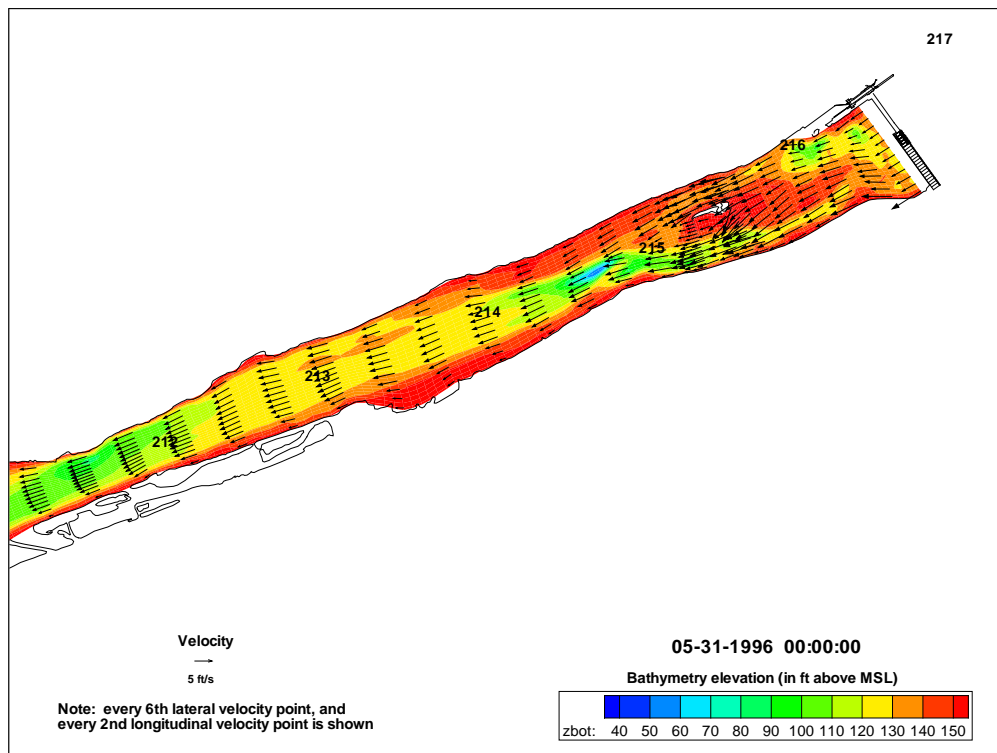


Figure 45. Spatial velocity distribution during the Spring 1996 study period.

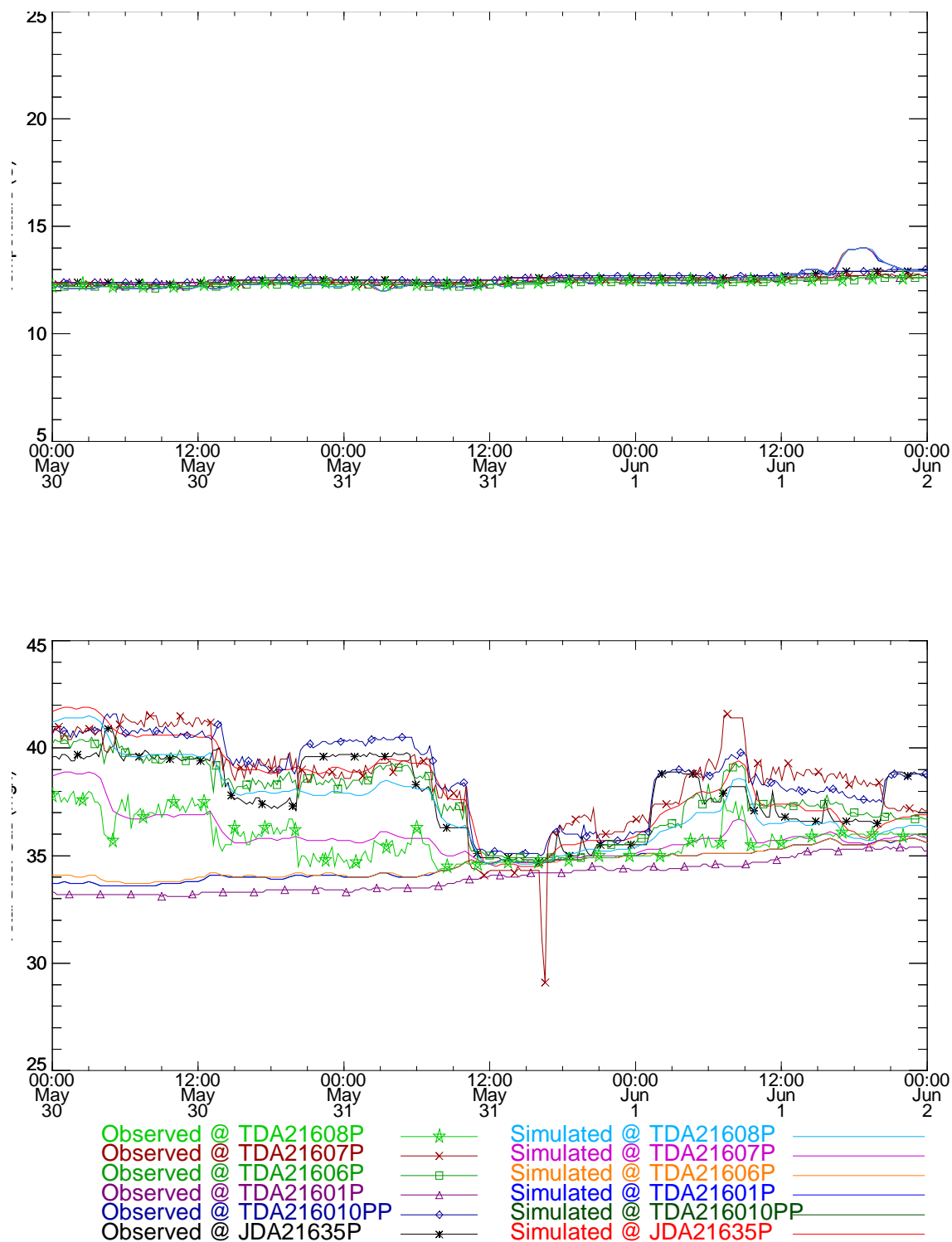
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## **1.4 Water Quality Calibration and Verification**

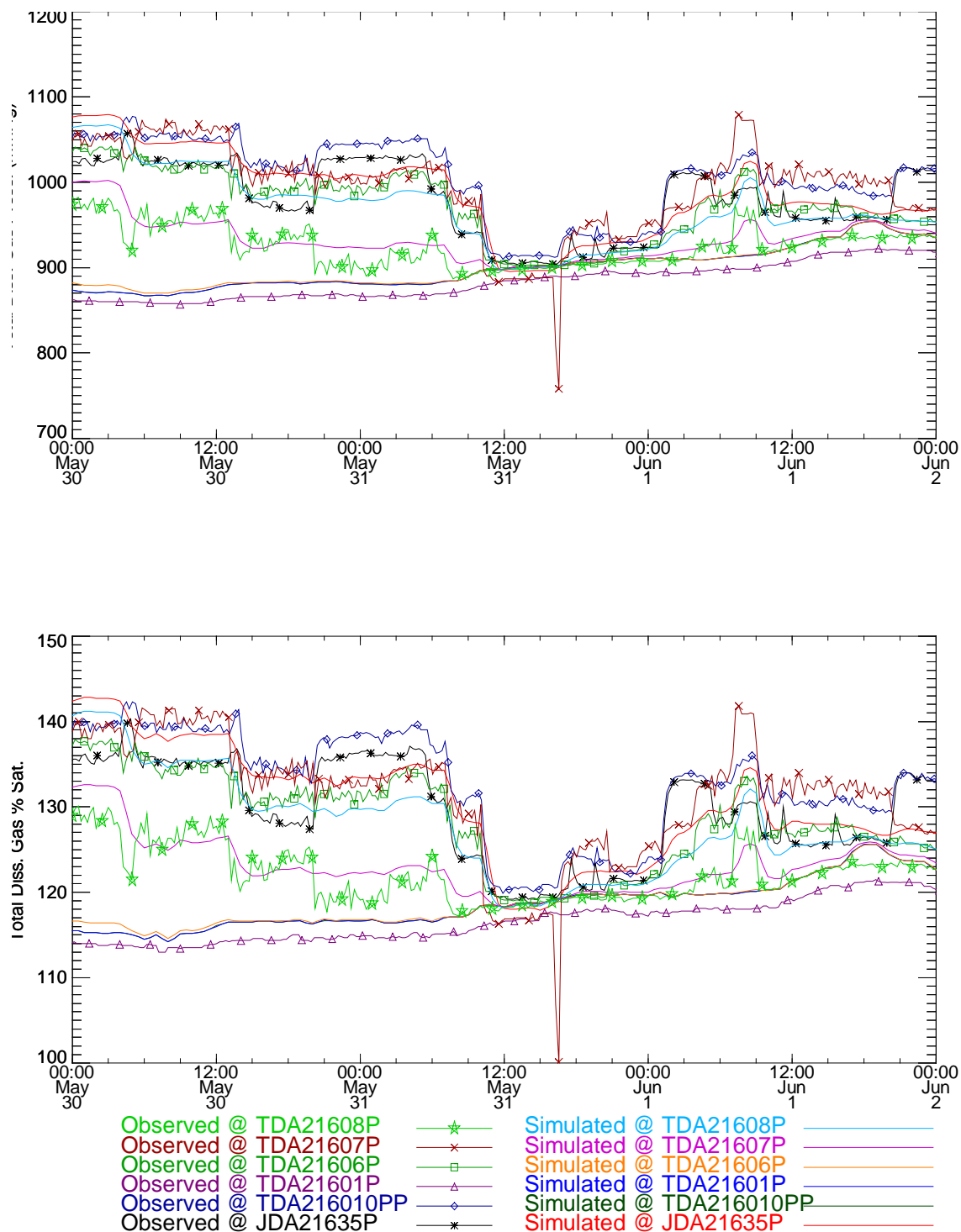
### ***1.4.1 1996 Spring Simulation***

#### **Boundary Conditions using John Day Sourcing Function and Forebay FMS Data**

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.



**Figure 46. Temperature and total dissolved gas time series near Columbia River Mile 216 for the Spring 1996 pool study (FMS-BC).**



**Figure 47. Total dissolved gas time series comparisons near Columbia River Mile 216 for the Spring 1996 pool study (FMS-BC).**

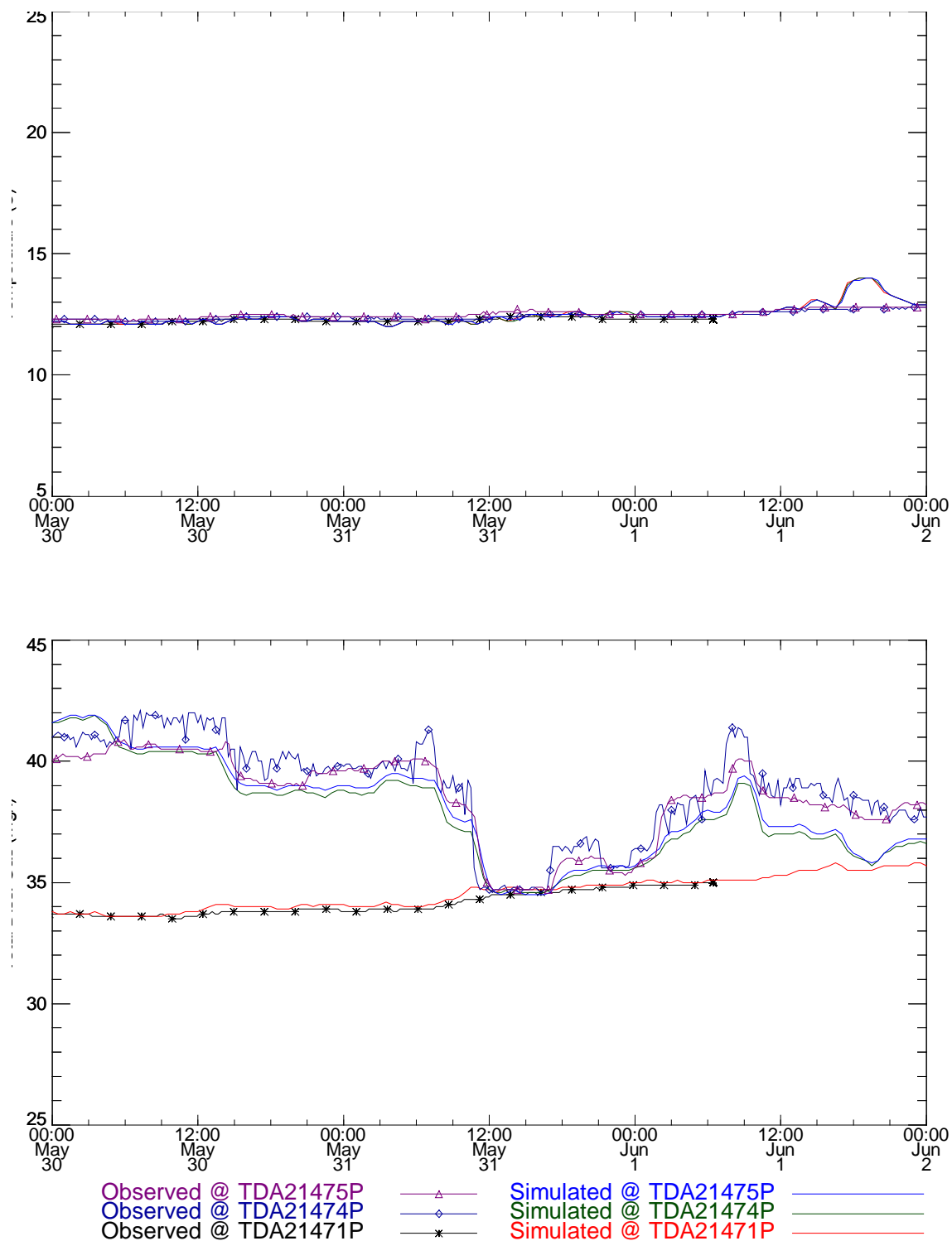
**Table 1. Statistical summary of measurements and simulations near river mile 216 for the Spring 1996 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
JDA21635P	12.56	12.45	0.16	0.40	0.30
TDA216010P	12.62	12.45	0.17	0.41	0.32
TDA21601P	12.51	12.45	0.11	0.41	0.34
TDA21606P	12.34	12.45	0.13	0.41	0.33
TDA21607P	12.42	12.45	0.15	0.41	0.29
TDA21608P	12.39	12.45	0.12	0.41	0.33
Concentration (mg/l)					
JDA21635P	37.76	38.05	1.73	2.03	1.10
TDA216010P	38.68	34.58	1.84	0.68	4.71
TDA21601P	34.03	34.58	0.74	0.68	0.57
TDA21606P	37.64	34.62	1.63	0.62	3.66
TDA21607P	38.44	35.91	2.06	0.97	2.93
TDA21608P	35.75	37.32	0.93	1.83	2.02
Gas Pressure (mmHg)					
JDA21635P	980.75	988.15	43.23	48.30	27.13
TDA216010P	1005.53	899.34	45.80	23.83	122.35
TDA21601P	883.84	899.32	20.66	23.82	16.08
TDA21606P	973.10	900.53	40.37	22.65	91.15
TDA21607P	995.21	933.31	51.72	24.24	72.77
TDA21608P	925.68	969.57	23.38	43.69	52.78
% Saturation					
JDA21635P	129.41	130.36	5.88	6.58	3.58
TDA216010P	132.68	118.62	6.23	2.86	16.20
TDA21601P	116.61	118.62	2.43	2.86	2.09
TDA21606P	128.39	118.78	5.52	2.71	12.08
TDA21607P	131.31	123.11	6.94	3.28	9.63
TDA21608P	122.13	127.90	3.15	5.96	6.96

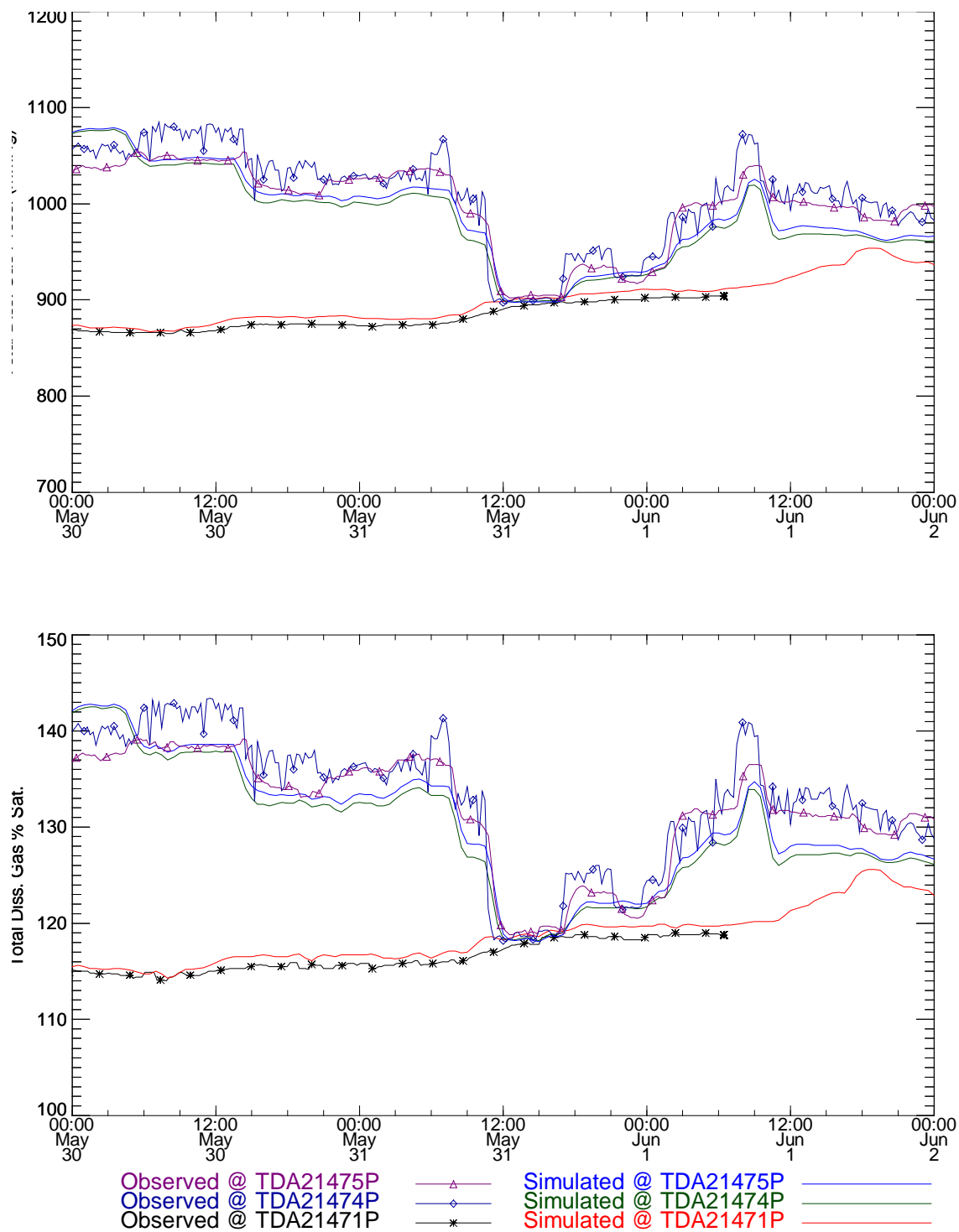
**Table 2. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 216 for the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
JDA21635P	98.62	60	79.31	79.31
TDA216010P	98.62	13.1	22.76	22.76
TDA21601P	95.86	100	100	100
TDA21606P	95.86	23.45	38.62	37.93
TDA21607P	96.55	10.34	21.38	20.69
TDA21608P	95.86	42.07	48.97	48.97





**Figure 48. Temperature and total dissolved gas time series near Columbia River Mile 214.7 for the Spring 1996 pool study (FMS-BC).**



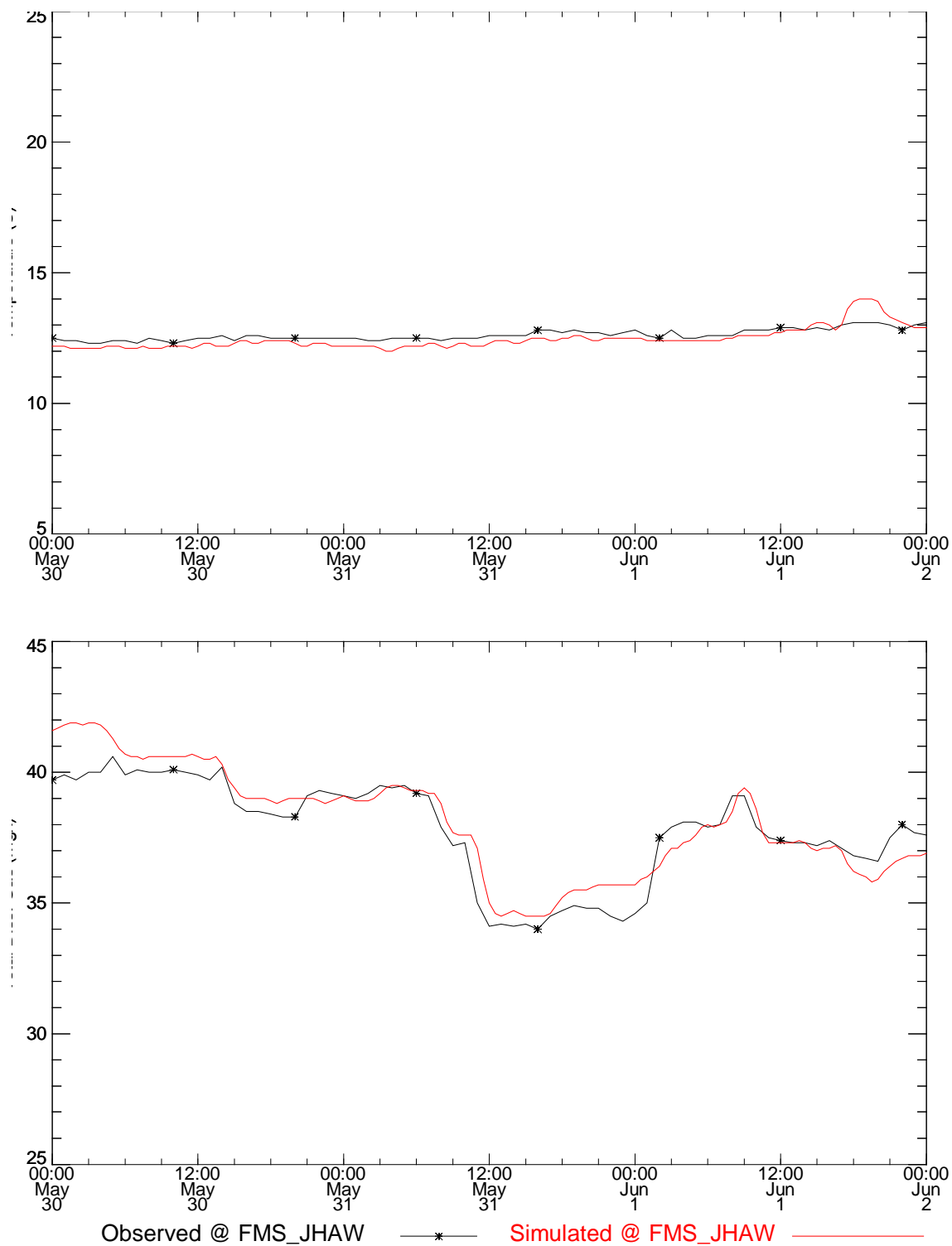
**Figure 49. Total dissolved gas time series comparisons near Columbia River Mile 214.7 for the Spring 1996 pool study (FMS-BC).**

**Table 3. Statistical summary of measurements and simulations near river mile 214.7 during the Spring 1996 pool study (FMS-BC).**

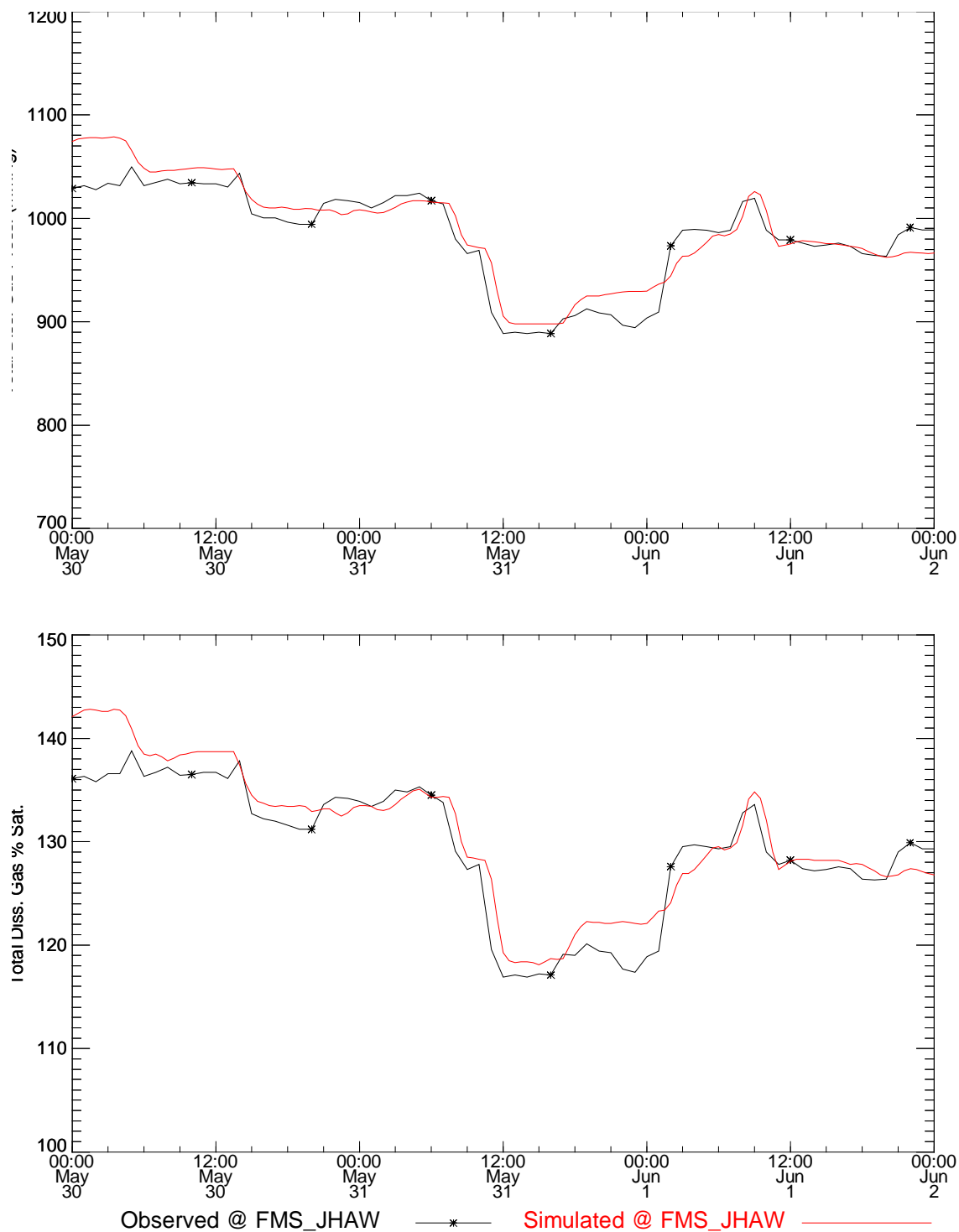
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA21471P	12.26	12.46	0.09	0.41	0.43
TDA21474P	12.44	12.46	0.16	0.41	0.28
TDA21475P	12.50	12.46	0.16	0.41	0.29
Concentration (mg/l)					
TDA21471P	34.34	34.57	0.56	0.67	0.30
TDA21474P	38.91	37.84	2.04	2.02	1.37
TDA21475P	38.48	38.06	1.81	2.05	0.86
Gas Pressure (mmHg)					
TDA21471P	887.01	899.16	15.22	23.8	16.83
TDA21474P	1007.62	982.94	50.78	48.12	31.85
TDA21475P	998.05	988.56	44.65	48.75	19.55
% Saturation					
TDA21471P	117.02	118.6	1.70	2.86	2.23
TDA21474P	132.95	129.67	6.87	6.56	4.24
TDA21475P	131.69	130.41	6.06	6.64	2.60

**Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 214.7 during the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA21471P	95.17	100	93.79	93.79
TDA21474P	97.24	41.38	74.48	75.17
TDA21475P	96.55	70.34	94.48	94.48



**Figure 50. Temperature and total dissolved gas time series at the JHAW fixed monitor station for the Spring 1996 pool study (FMS-BC).**



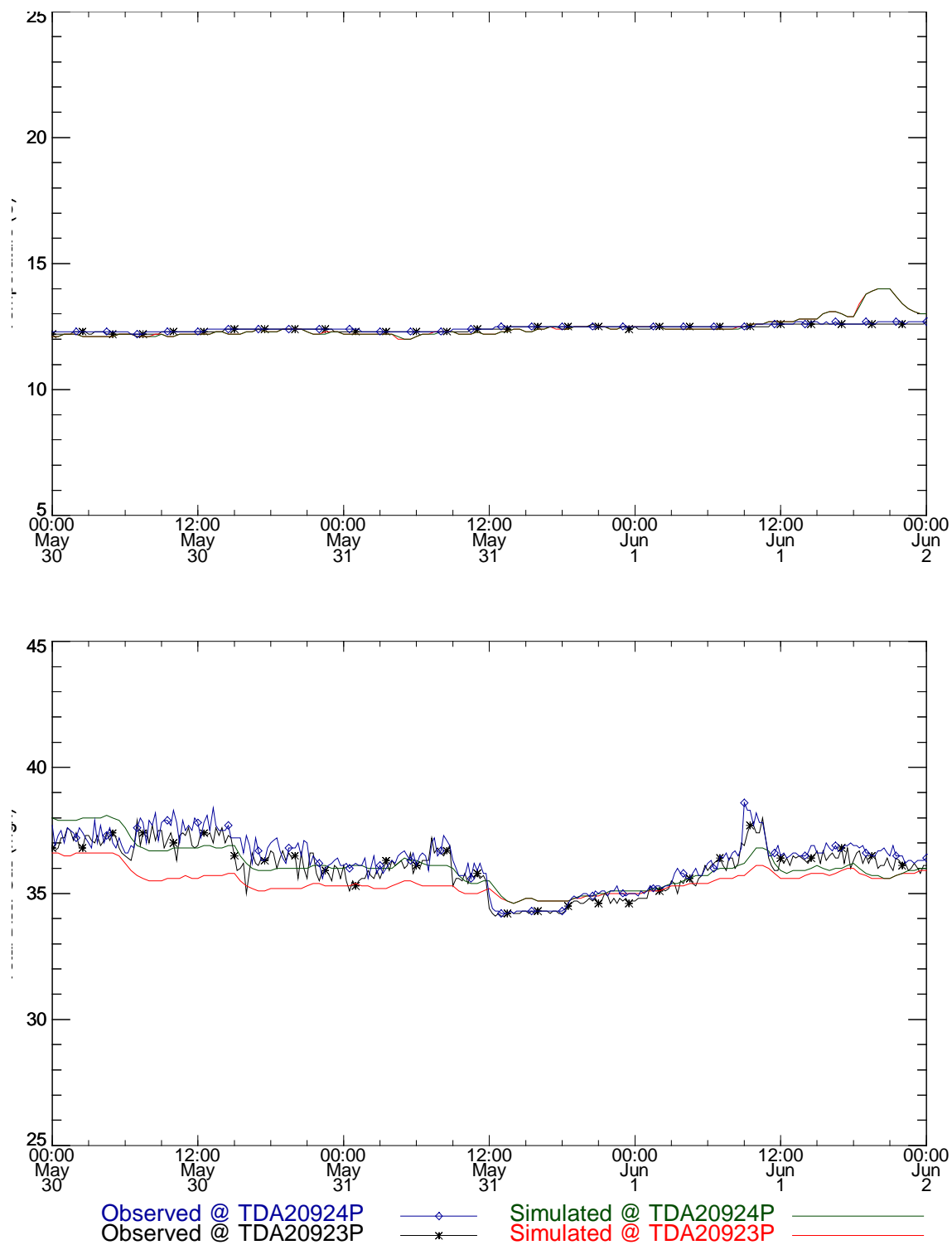
**Figure 51. Total dissolved gas time series comparisons at the JHAW fixed monitor for the Spring 1996 pool study (FMS-BC).**

**Table 5. Statistical summary of measurements and simulations at the JHAW fixed monitor for the Spring 1996 pool study (FMS-BC).**

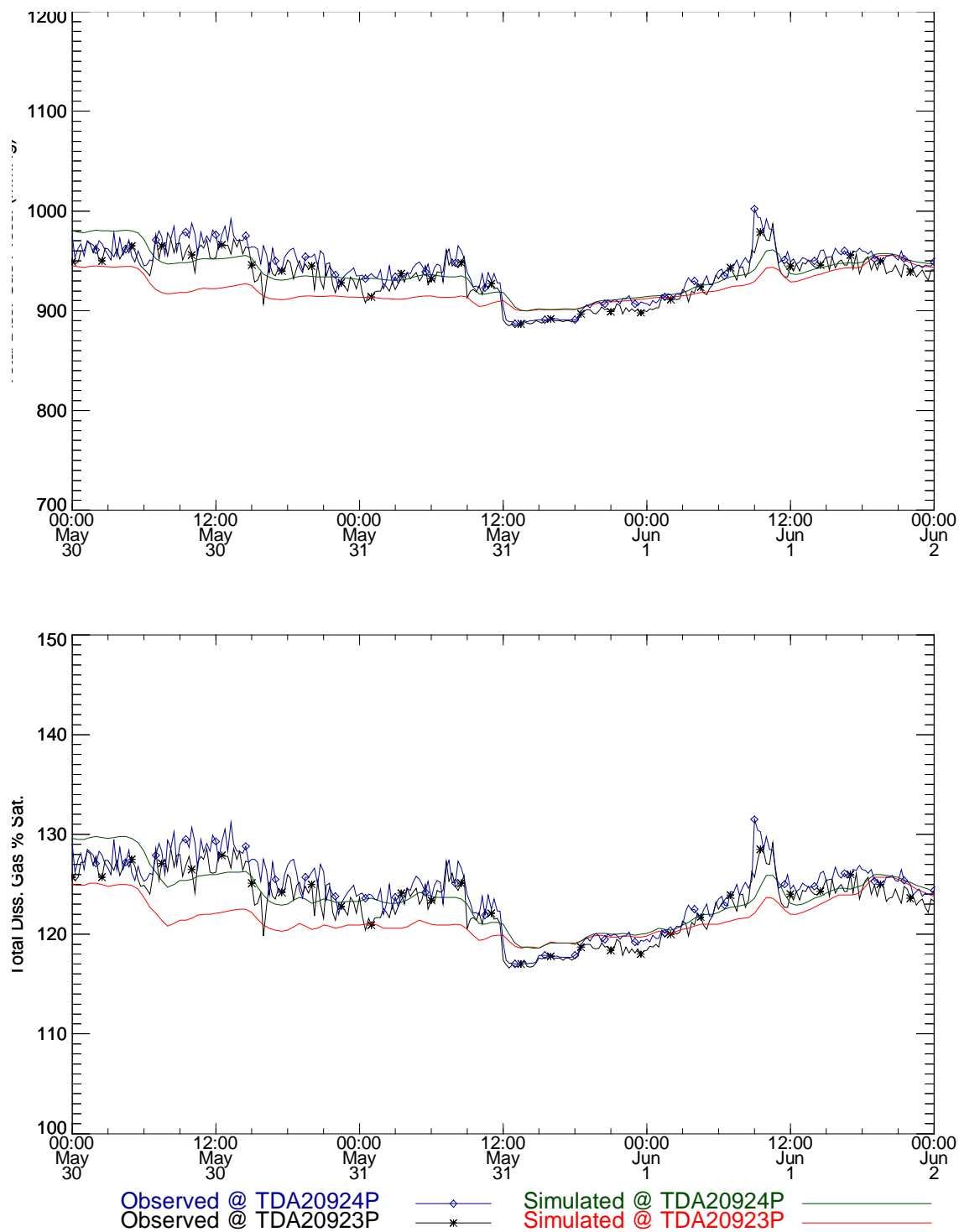
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_JHAW	12.62	12.47	0.20	0.41	0.29
Concentration (mg/l)					
FMS_JHAW	37.77	38.07	1.92	2.05	0.80
Gas Pressure (mmHg)					
FMS_JHAW	982.29	989.04	47.29	48.68	18.72
% Saturation					
FMS_JHAW	129.26	130.47	6.44	6.63	2.52

**Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the JHAW fixed monitor during the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_JHAW	100	82.76	93.10	93.10



**Figure 52. Temperature and total dissolved gas time series near Columbia River Mile 209.2 for the Spring 1996 pool study (FMS-BC).**



**Figure 53. Total dissolved gas time series comparisons near Columbia River Mile 209.2 for the Spring 1996 pool study (FMS-BC).**

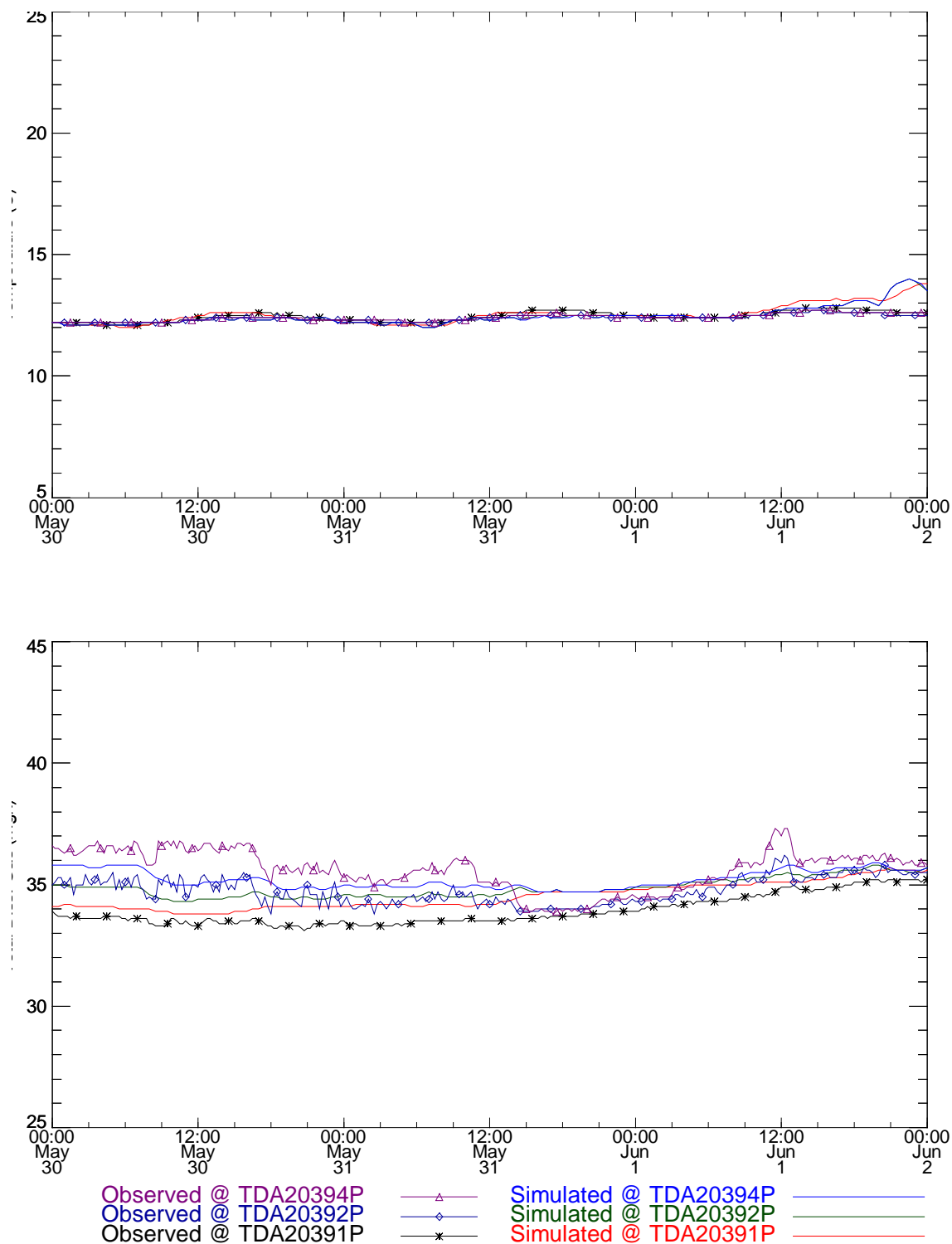


**Table 7. Statistical summary of measurements and simulations near river mile 209.2 during the Spring 1996 pool study (FMS-BC).**

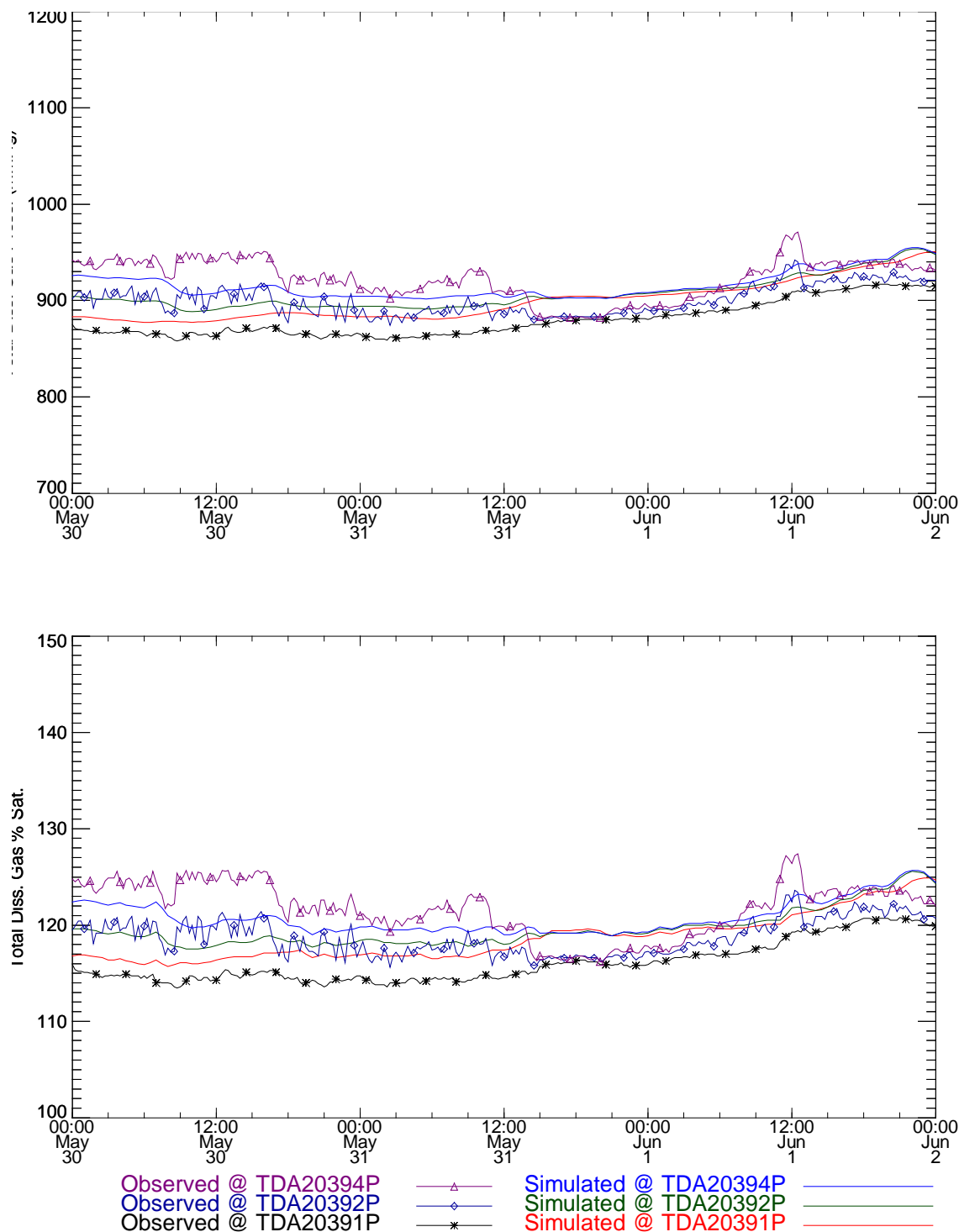
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA20923P	12.42	12.46	0.13	0.41	0.32
TDA20924P	12.45	12.45	0.13	0.41	0.31
Concentration (mg/l)					
TDA20923P	36.04	35.48	0.98	0.48	0.89
TDA20924P	36.34	36.04	1.04	0.84	0.67
Gas Pressure (mmHg)					
TDA20923P	933.63	922.42	24.28	15.03	21.41
TDA20924P	941.99	936.97	25.95	20.75	15.33
% Saturation					
TDA20923P	123.18	121.67	3.24	1.91	2.83
TDA20924P	124.28	123.59	3.47	2.82	2.02

**Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 209.2 during the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA20923P	95.86	77.24	90.34	89.66
TDA20924P	96.55	91.03	97.93	97.24



**Figure 54. Temperature and total dissolved gas time series near Columbia River Mile 203.9 for the Spring 1996 pool study (FMS-BC).**



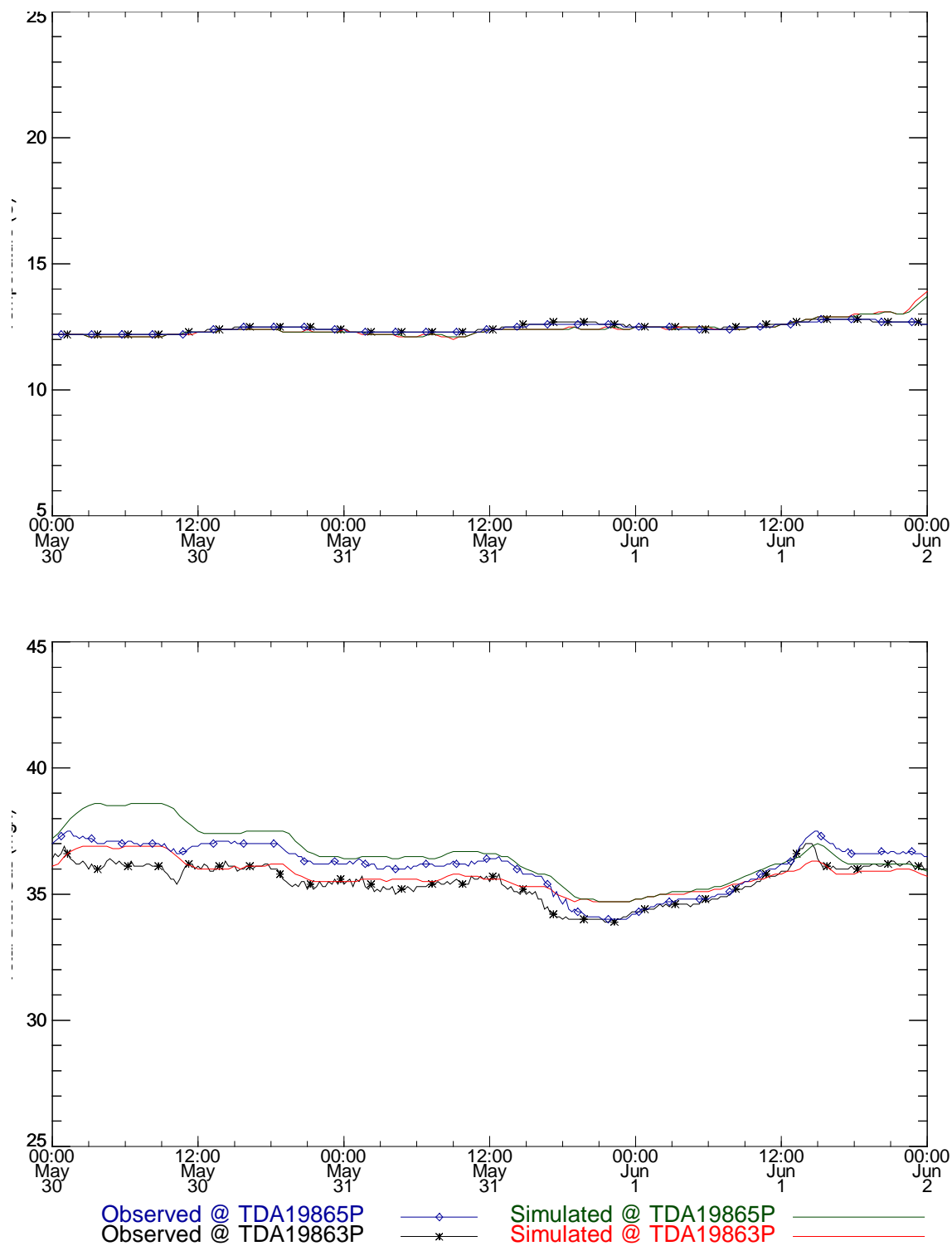
**Figure 55. Total dissolved gas time series comparisons near Columbia River Mile 203.9 for the Spring 1996 pool study (FMS-BC).**

**Table 9. Statistical summary of measurements and simulations near river mile 203.9 during the Spring 1996 pool study (FMS-BC).**

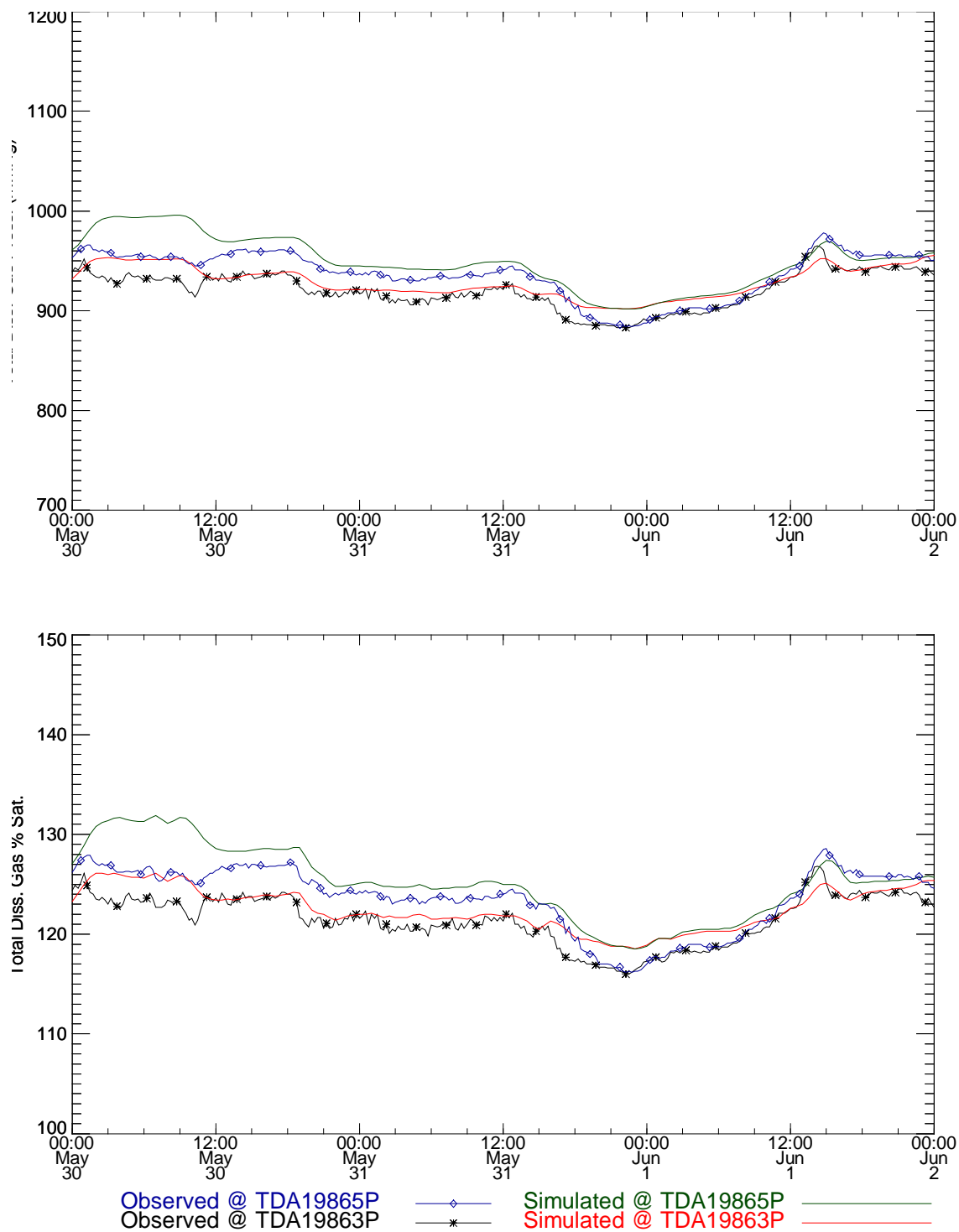
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA20391P	12.45	12.52	0.21	0.39	0.26
TDA20392P	12.38	12.46	0.14	0.38	0.32
TDA20394P	12.40	12.46	0.14	0.39	0.30
Concentration (mg/l)					
TDA20391P	33.91	34.53	0.60	0.54	0.66
TDA20392P	34.76	34.86	0.55	0.40	0.45
TDA20394P	35.61	35.21	0.84	0.37	0.76
Gas Pressure (mmHg)					
TDA20391P	879.75	899.35	18.09	20.29	20.22
TDA20392P	900.07	906.88	15.06	16.61	14.27
TDA20394P	922.19	915.82	21.08	14.20	18.65
% Saturation					
TDA20391P	116.07	118.62	2.11	2.40	2.65
TDA20392P	118.75	119.62	1.84	1.95	1.88
TDA20394P	121.67	120.80	2.80	1.72	2.48

**Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 203.9 during the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA20391P	97.93	100	100	100
TDA20392P	95.86	99.31	100	100
TDA20394P	96.55	84.14	96.55	95.86



**Figure 56. Temperature and total dissolved gas time series near Columbia River Mile 198.6 for the Spring 1996 pool study (FMS-BC).**



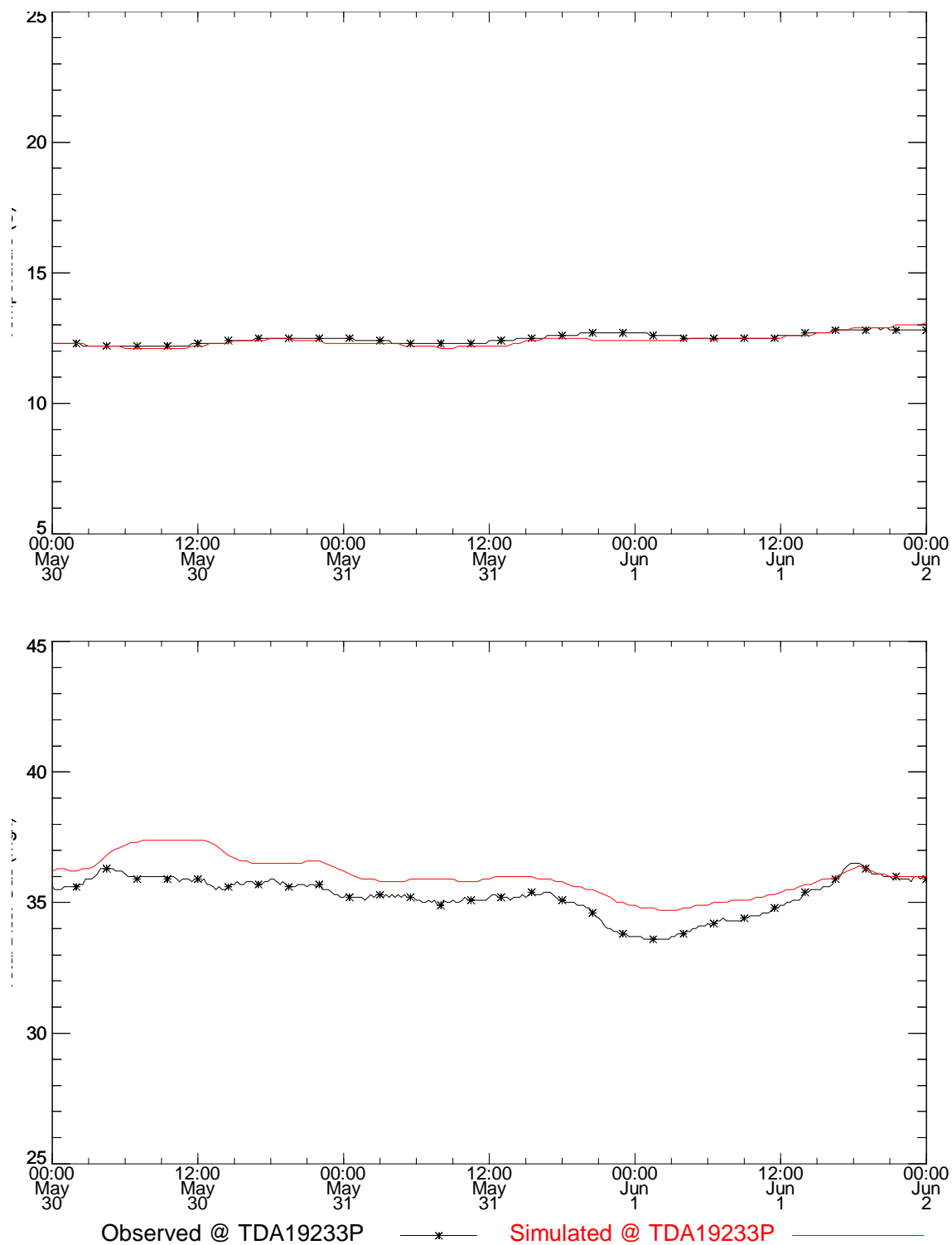
**Figure 57. Total dissolved gas time series comparisons near Columbia River Mile 198.6 for the Spring 1996 pool study (FMS-BC).**

**Table 11. Statistical summary of measurements and simulations near river mile 198.6 during the Spring 1996 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA19863P	12.46	12.43	0.18	0.32	0.22
TDA19865P	12.45	12.43	0.17	0.30	0.18
Concentration (mg/l)					
TDA19863P	35.49	35.74	0.74	0.59	0.46
TDA19865P	36.13	36.52	0.95	1.09	0.66
Gas Pressure (mmHg)					
TDA19863P	920.39	928.78	18.74	15.51	11.93
TDA19865P	936.61	948.74	23.66	26.23	17.17
% Saturation					
TDA19863P	121.43	122.51	2.50	2.10	1.59
TDA19865P	123.57	125.15	3.24	3.64	2.27

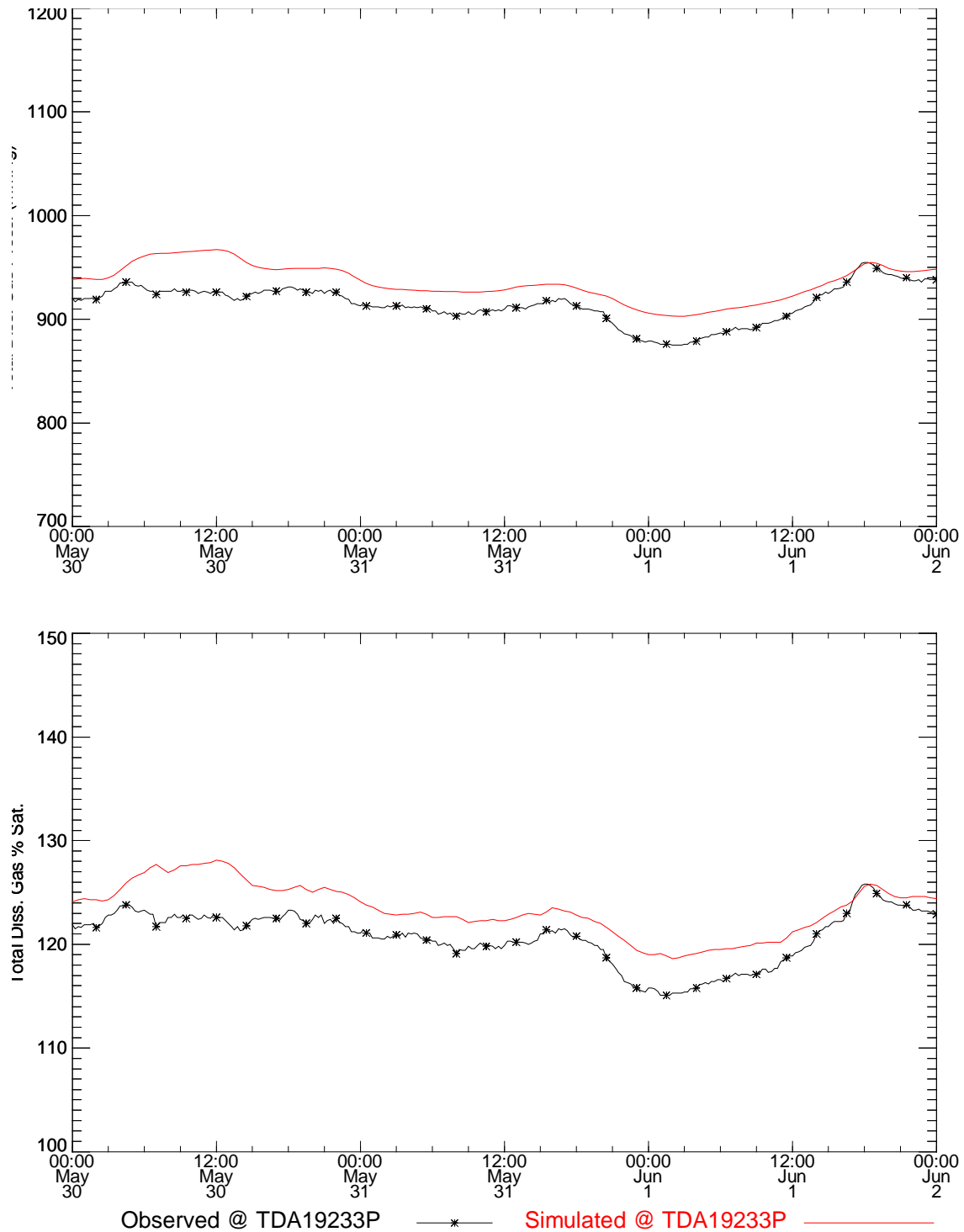
**Table 12. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 198.6 during the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA19863P	98.62	100	100	100
TDA19865P	99.31	87.59	90.34	92.41



**Figure 58. Temperature and total dissolved gas time series near Columbia River Mile 192.3 during the Spring 1996 pool study (FMS-BC).**





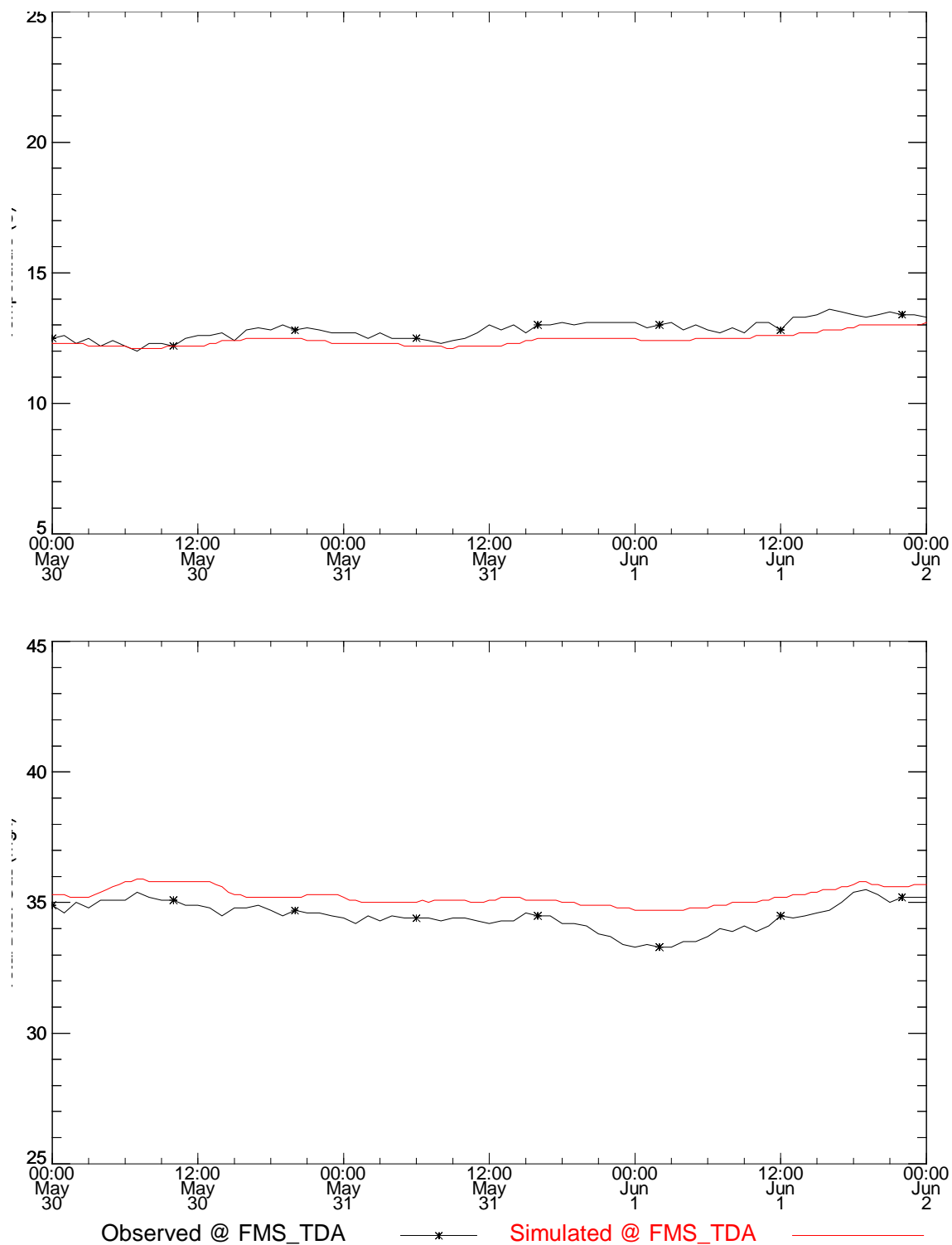
**Figure 59. Total dissolved gas time series comparisons near Columbia River Mile 192.3 during the Spring 1996 pool study (FMS-BC).**

**Table 13. Statistical summary of measurements and simulations near river mile 192.3 during the Spring 1996 pool study (FMS-BC).**

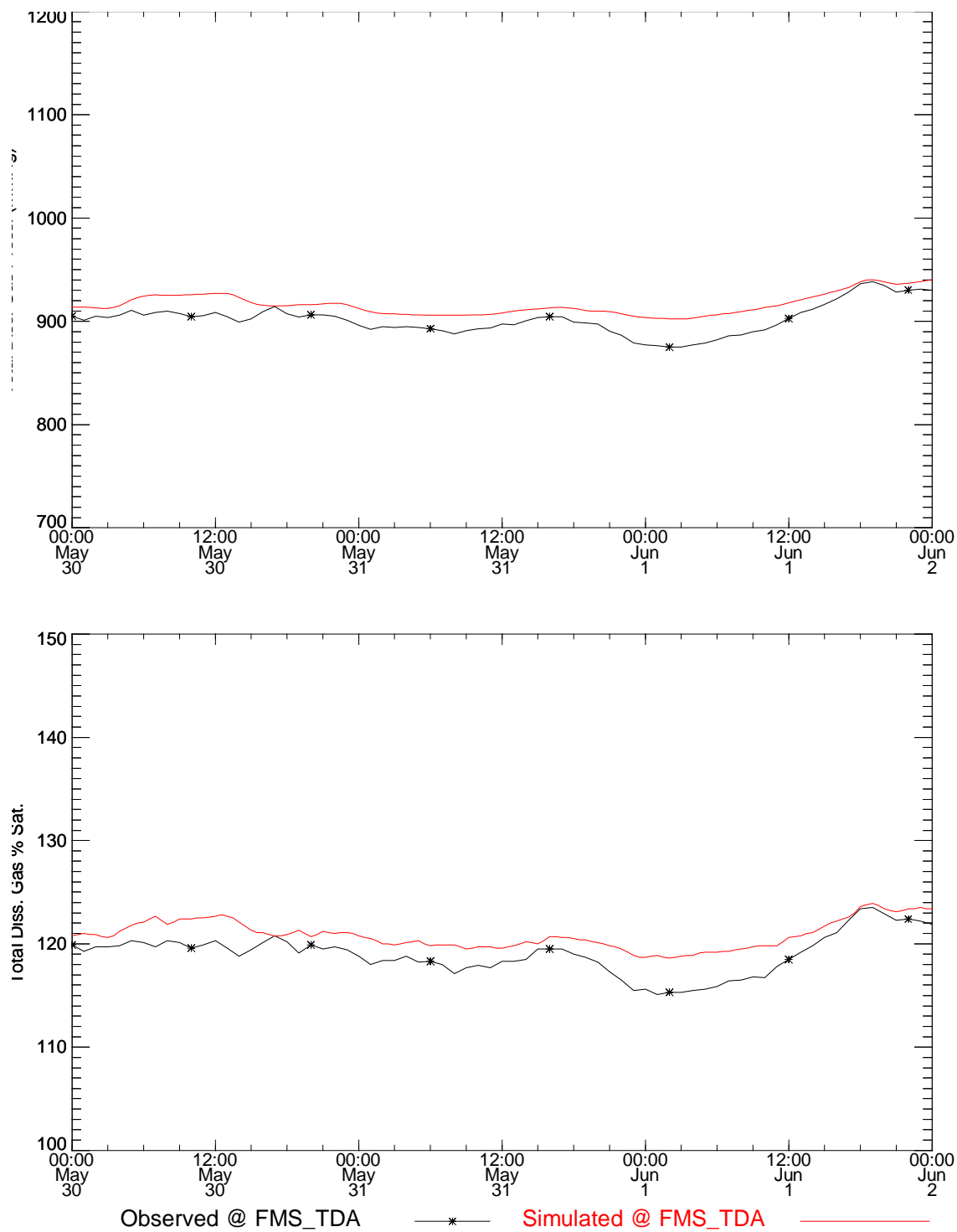
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA19233P	12.48	12.41	0.19	0.23	0.13
Concentration (mg/l)					
TDA19233P	35.25	36.01	0.73	0.72	0.86
Gas Pressure (mmHg)					
TDA19233P	914.63	935.3	18.37	17.60	22.61
% Saturation					
TDA19233P	120.68	123.38	2.55	2.52	2.97

**Table 14. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 192.3 during the Spring 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA19233P	100	80.00	93.10	93.10



**Figure 60. Temperature and total dissolved gas time series at the TDA fixed monitor during the Spring 1996 pool study (FMS-BC).**



**Figure 61. Total dissolved gas time series comparisons at the TDA fixed monitor during the Spring 1996 pool study (FMS-BC).**

**Table 15. Statistical summary of measurements and simulations at the TDA fixed monitor during the Spring 1996 pool study (FMS-BC).**

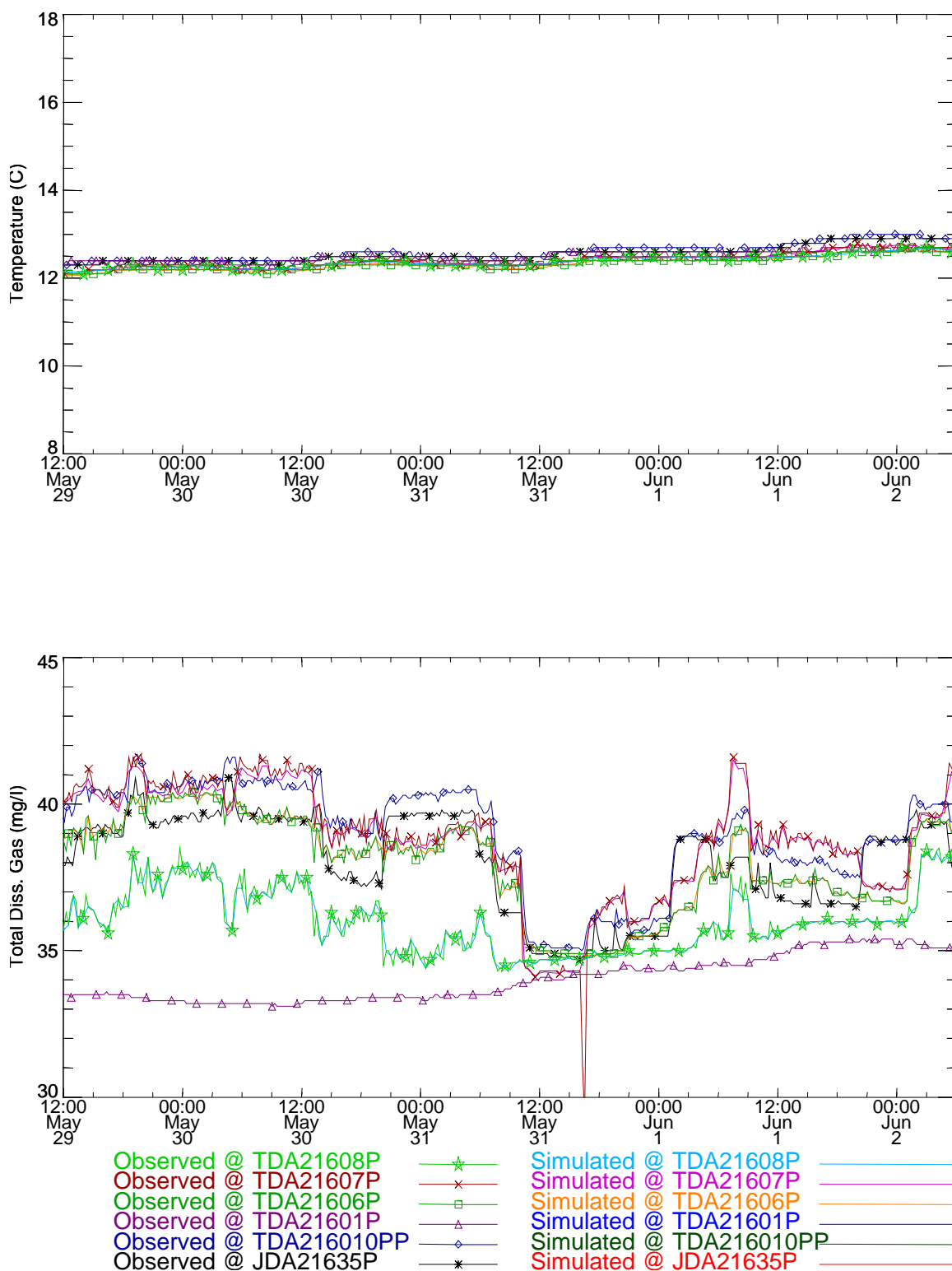
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_TDA	12.82	12.44	0.36	0.24	0.43
Concentration (mg/l)					
FMS_TDA	34.48	35.24	0.54	0.33	0.81
Gas Pressure (mmHg)					
FMS_TDA	901.56	915.98	14.66	10.22	15.84
% Saturation					
FMS_TDA	118.94	120.83	1.96	1.35	2.09

**Table 16. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the TDA fixed monitor during the Spring 1996 study (FMS-BC).**

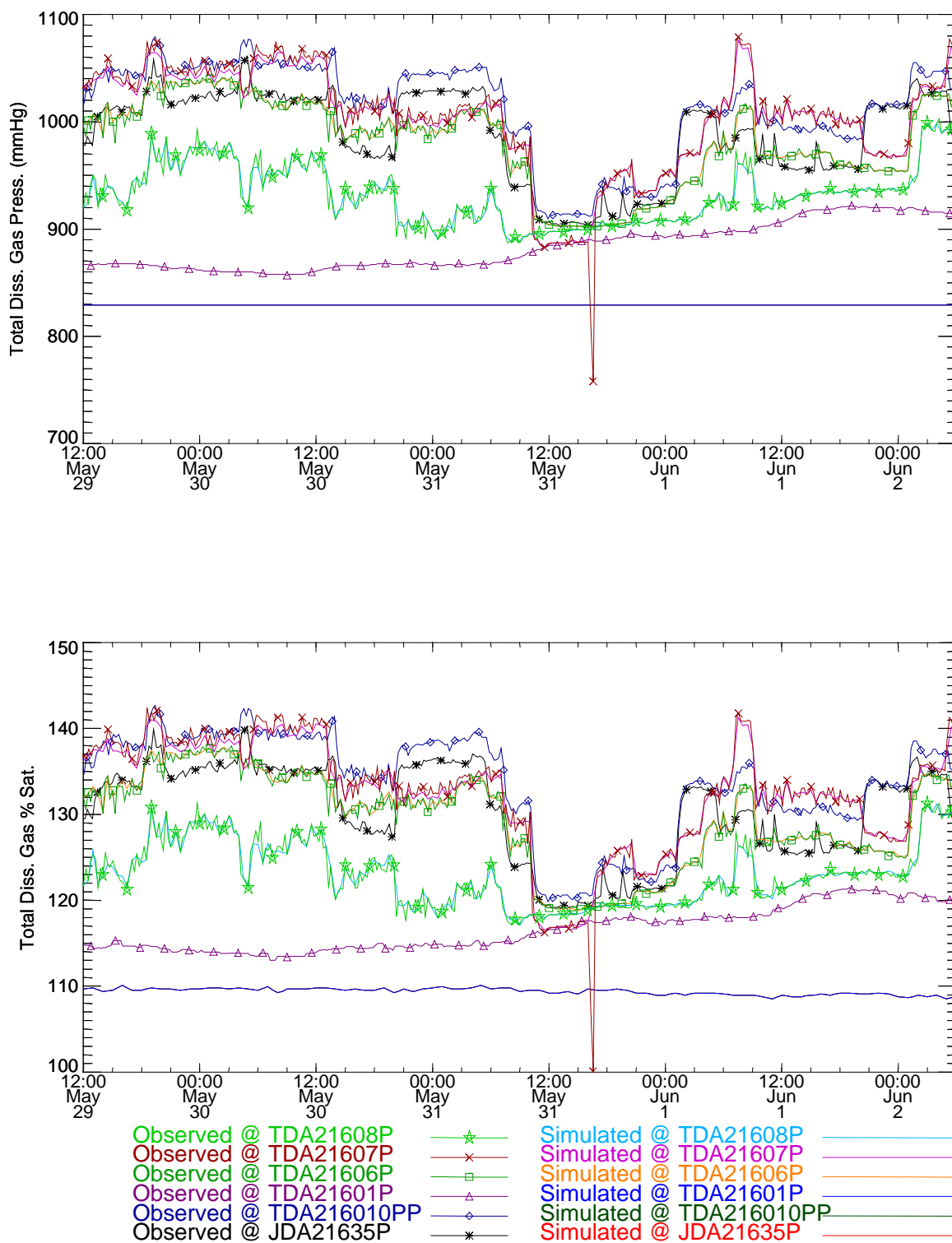
Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_TDA	100	82.76	100	100

### **Boundary Conditions using Temporary Monitored Field Data**

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.



**Figure 62. Temperature and total dissolved gas time series near Columbia River Mile 216 for the Spring 1996 pool study (TM-BC).**



**Figure 63. Total dissolved gas time series comparisons near Columbia River Mile 216 for the Spring 1996 pool study (TM-BC).**

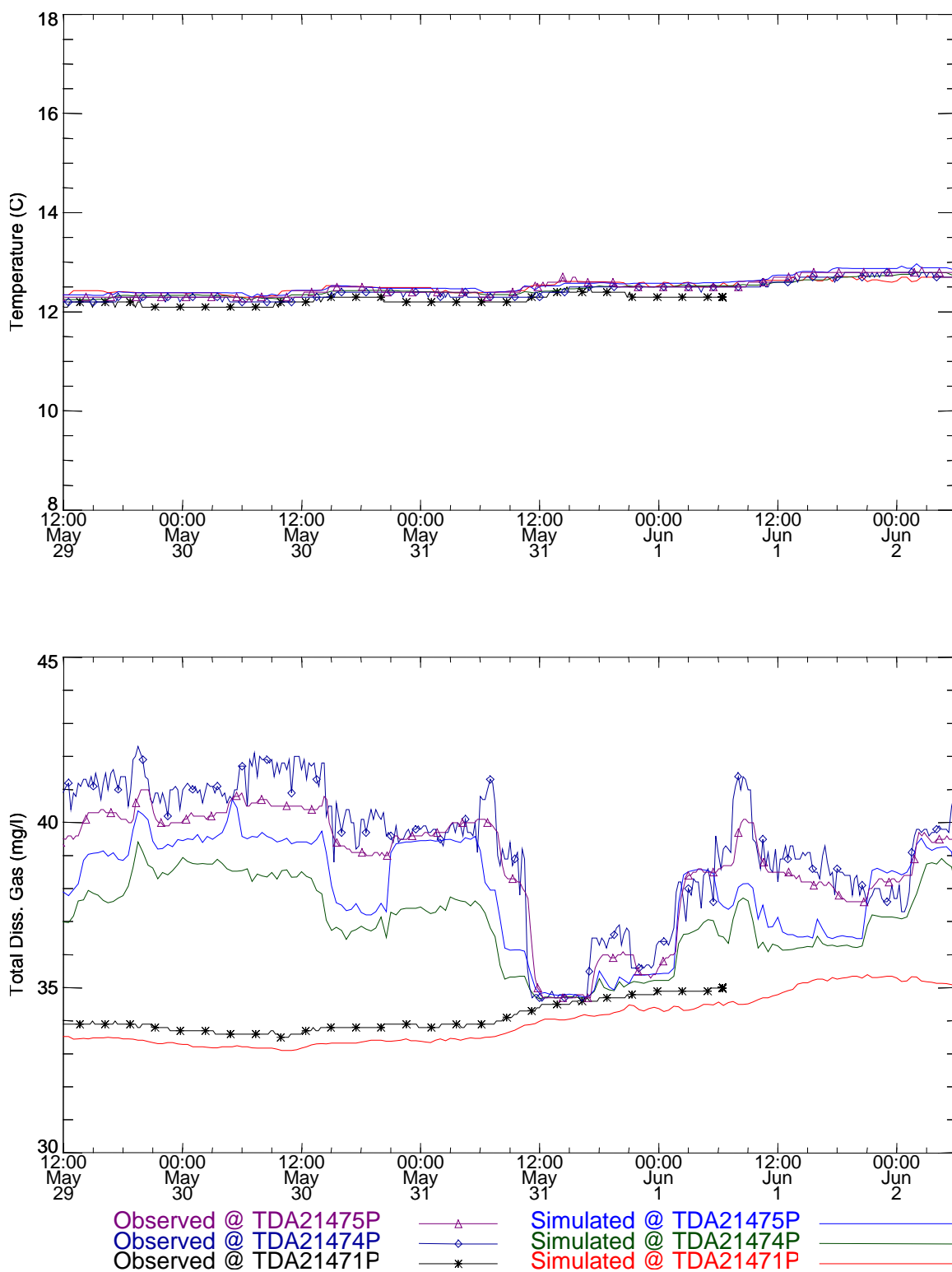
**Table 17. Statistical summary of measurements and simulations near river mile 216 for the Spring 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
JDA21635P	12.56	25	0.18	0	12.45
TDA216010P	12.61	25	0.19	0	12.4
TDA21601P	12.5	25	0.11	0	12.5
TDA21606P	12.33	12.33	0.15	0.15	0.03
TDA21607P	12.42	12.41	0.17	0.17	0.03
TDA21608P	12.38	12.38	0.15	0.14	0.03
Concentration					
JDA21635P	38.04	25	1.67	0	13.14
TDA216010P	38.99	25	1.78	0	14.1
TDA21601P	34.03	25	0.76	0	9.06
TDA21606P	37.98	37.96	1.65	1.65	0.04
TDA21607P	38.81	38.74	2.03	1.86	0.42
TDA21608P	36.01	35.99	1.06	1.06	0.04
Gas Pressure					
JDA21635P	987.8	829.14	41.85	0	164.08
TDA216010P	1013.32	829.14	44.24	0	189.42
TDA21601P	883.68	829.14	21.36	0	58.57
TDA21606P	981.47	981.55	40.86	40.89	0.69
TDA21607P	1004.45	1002.96	50.78	46.5	10.69
TDA21608P	932.1	932.1	27.17	27.11	0.5
% Saturation					
JDA21635P	130.33	109.4	5.66	0.36	21.66
TDA216010P	133.7	109.4	6	0.36	25
TDA21601P	116.58	109.4	2.49	0.36	7.71
TDA21606P	129.49	129.51	5.55	5.55	0.25
TDA21607P	132.52	132.33	6.81	6.23	1.43
TDA21608P	122.97	122.98	3.58	3.57	0.22

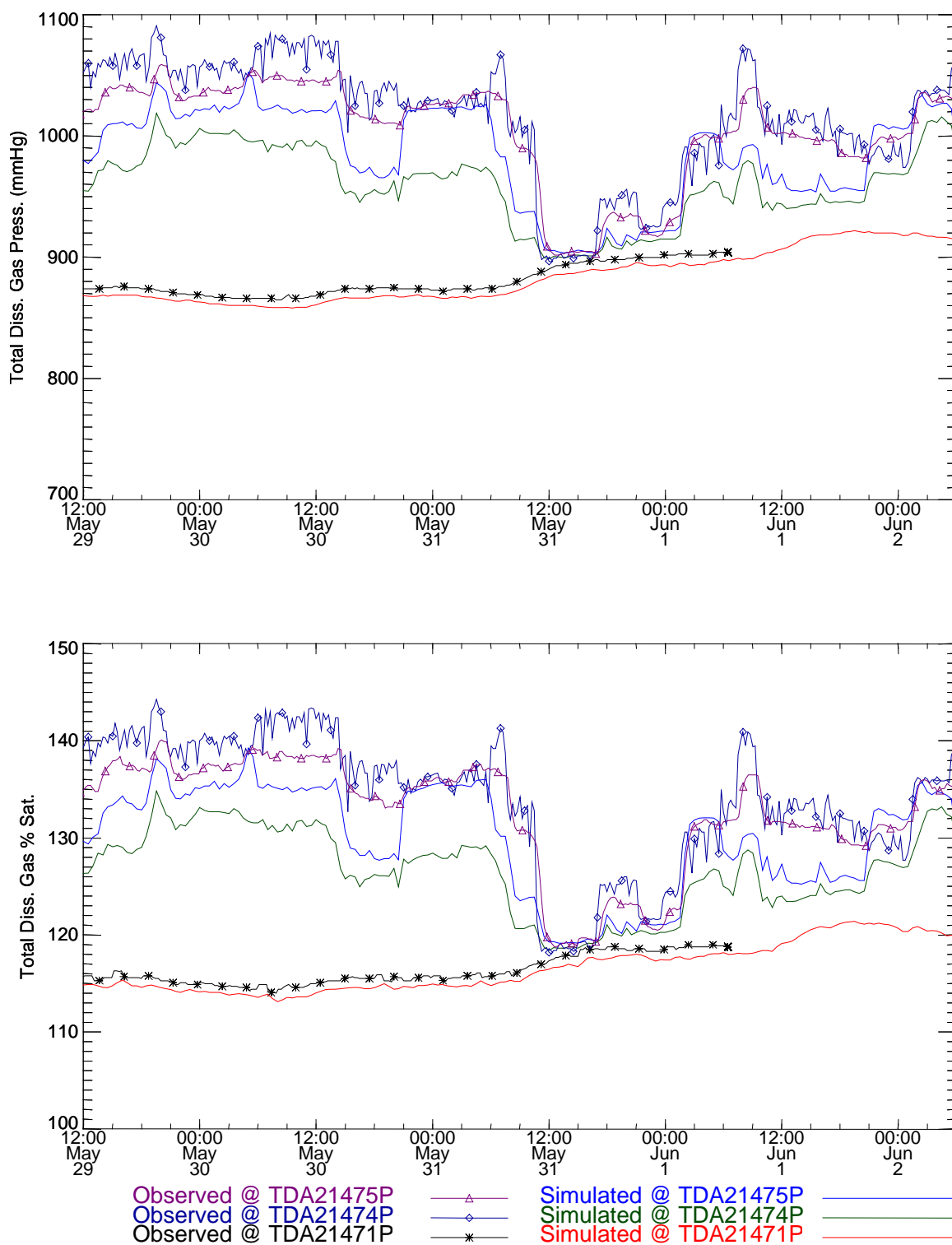
**Table 18. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 216 for the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
JDA21635P	0	0	0	0
TDA216010P	0	0	0	0
TDA21601P	0	0	35.36	32.6
TDA21606P	100	100	100	100
TDA21607P	100	99.45	99.45	99.45
TDA21608P	100	100	100	100





**Figure 64. Temperature and total dissolved gas time series near Columbia River Mile 214.7 for the Spring 1996 pool study (TM-BC).**



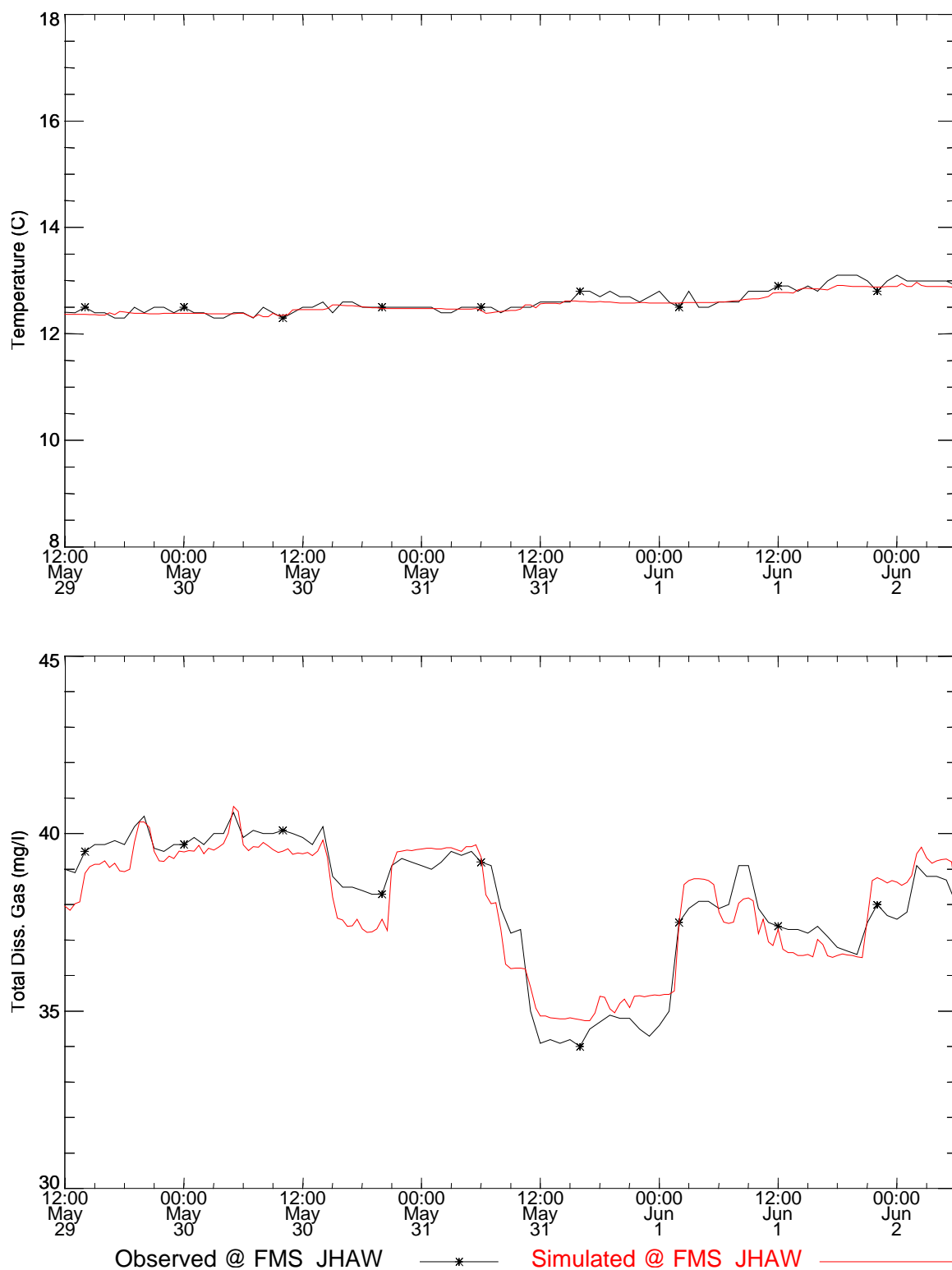
**Figure 65. Total dissolved gas time series comparisons near Columbia River Mile 214.7 for the Spring 1996 pool study (TM-BC).**

**Table 19. Statistical summary of measurements and simulations near river mile 214.7 during the Spring 1996 pool study (TM-BC).**

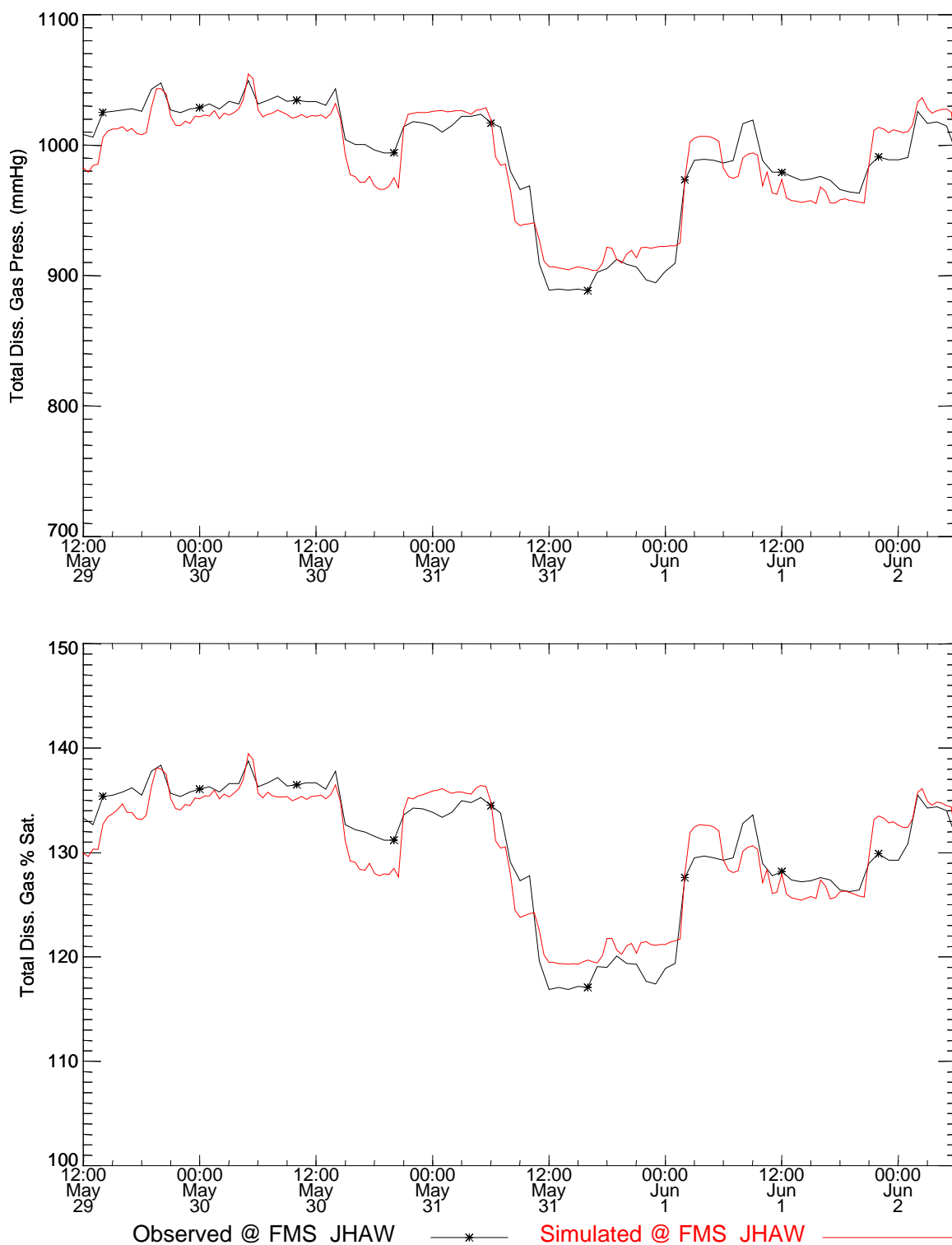
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA21471P	12.25	12.51	0.09	0.12	0.27
TDA21474P	12.44	12.46	0.18	0.15	0.05
TDA21475P	12.49	12.55	0.18	0.18	0.07
Concentration					
TDA21471P	34.32	34.01	0.56	0.75	0.42
TDA21474P	39.25	37.01	2	1.27	2.5
TDA21475P	38.75	37.92	1.73	1.64	1.09
Gas Pressure					
TDA21471P	886.3	883.88	15.18	21.21	8.74
TDA21474P	1016.03	959.86	49.56	31.81	62.9
TDA21475P	1004.85	985.06	42.61	41.14	26.85
% Saturation					
TDA21471P	116.94	116.61	1.69	2.48	1.17
TDA21474P	134.05	126.65	6.71	4.3	8.3
TDA21475P	132.58	129.97	5.78	5.57	3.54

**Table 20. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 214.7 during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA21471P	100	100	100	100
TDA21474P	100	17.13	24.31	24.86
TDA21475P	100	58.01	77.35	77.35



**Figure 66. Temperature and total dissolved gas time series at the JHAW fixed monitor station for the Spring 1996 pool study (TM-BC).**



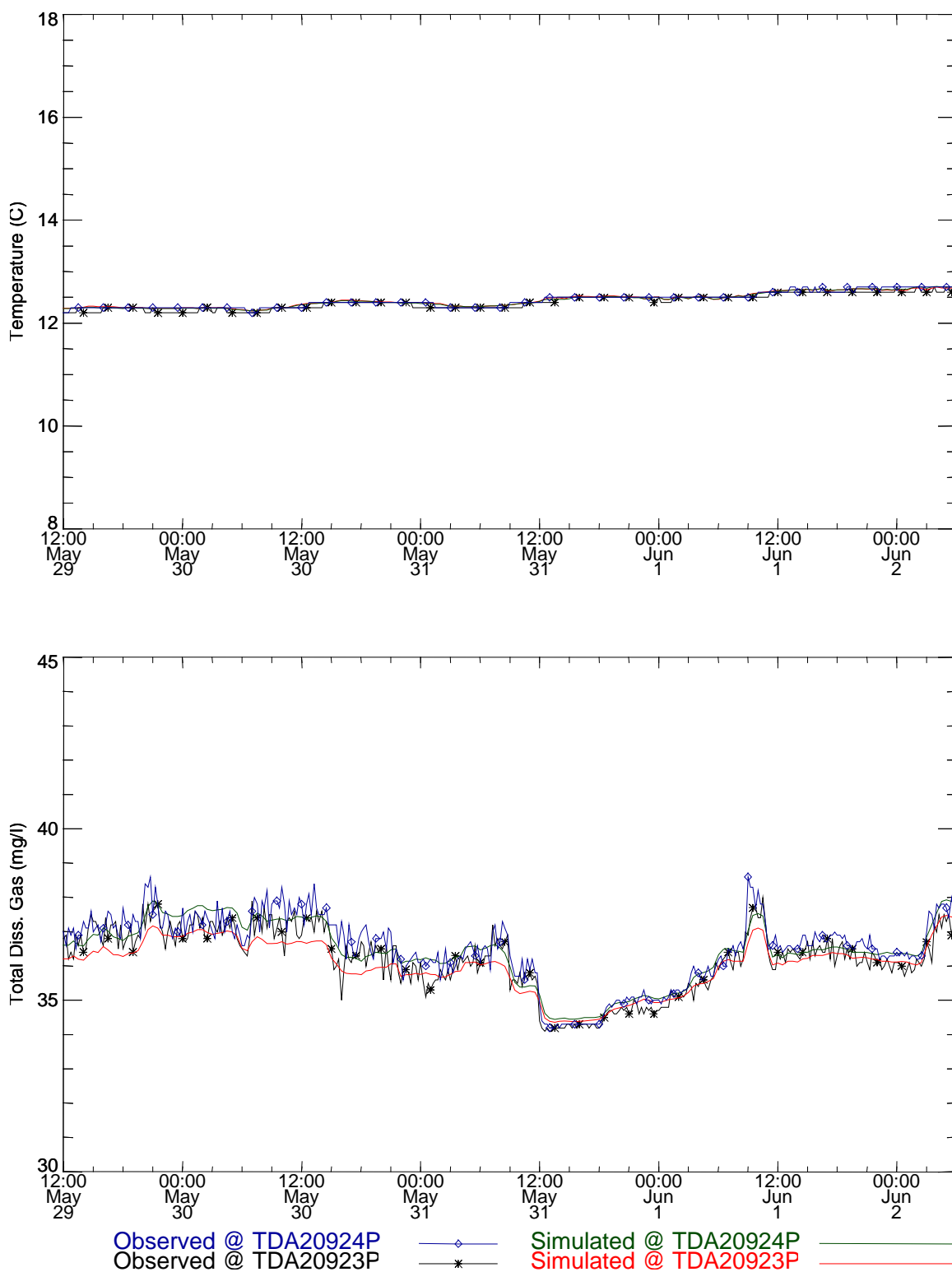
**Figure 67. Total dissolved gas time series comparisons at the JHAW fixed monitor for the Spring 1996 pool study (TM-BC).**

**Table 21. Statistical summary of measurements and simulations at the JHAW fixed monitor for the Spring 1996 pool study (TM-BC).**

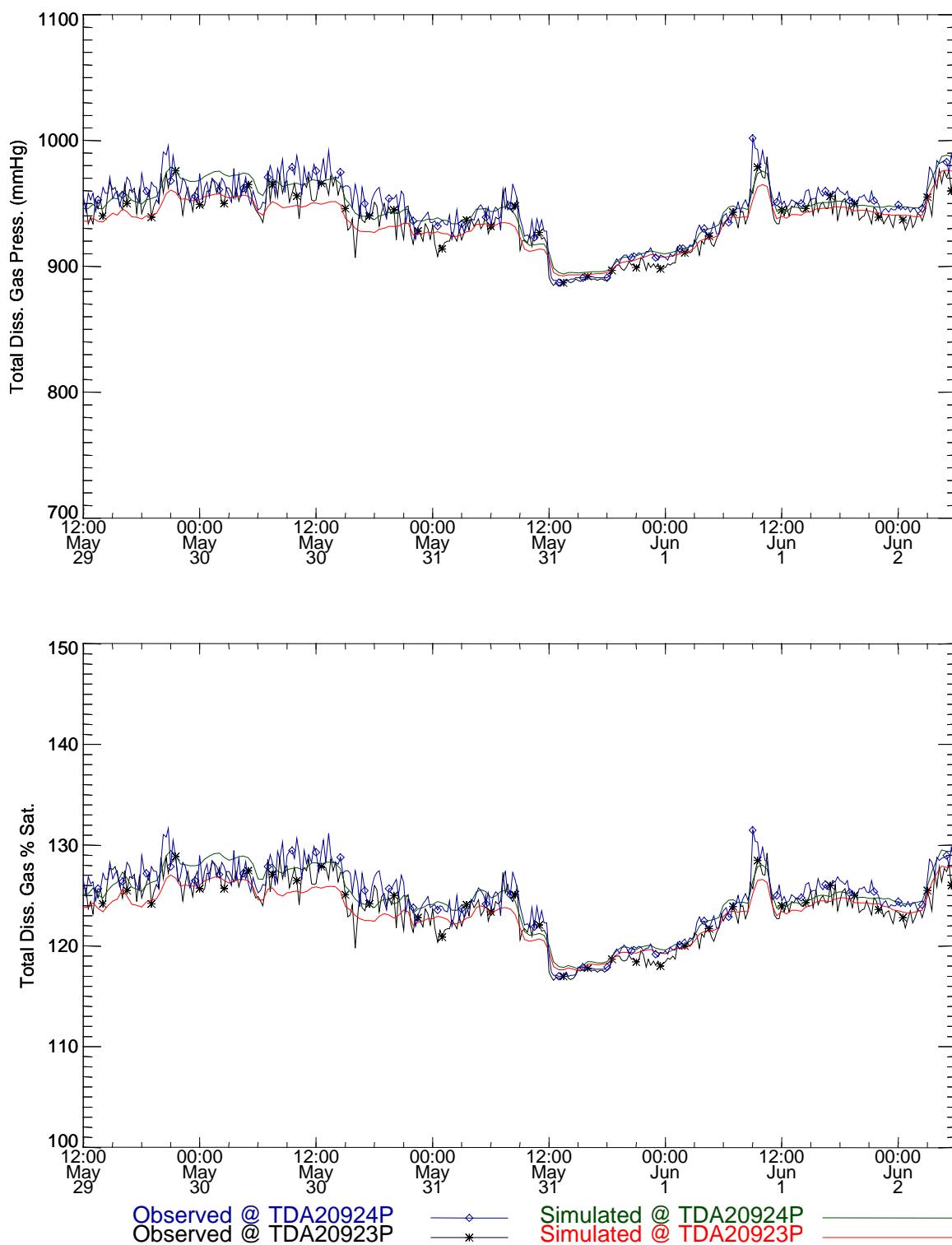
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_JHAW	12.62	12.57	0.22	0.18	0.09
Concentration					
FMS_JHAW	38.07	37.98	1.85	1.66	0.63
Gas Pressure					
FMS_JHAW	990.01	986.9	45.48	41.49	16.03
% Saturation					
FMS_JHAW	130.38	130.22	6.24	5.61	2.09

**Table 22. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the JHAW fixed monitor during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_JHAW	100	88.4	100	100



**Figure 68. Temperature and total dissolved gas time series near Columbia River Mile 209.2 for the Spring 1996 pool study (TM-BC).**



**Figure 69. Total dissolved gas time series comparisons near Columbia River Mile 209.2 for the Spring 1996 pool study (TM-BC).**

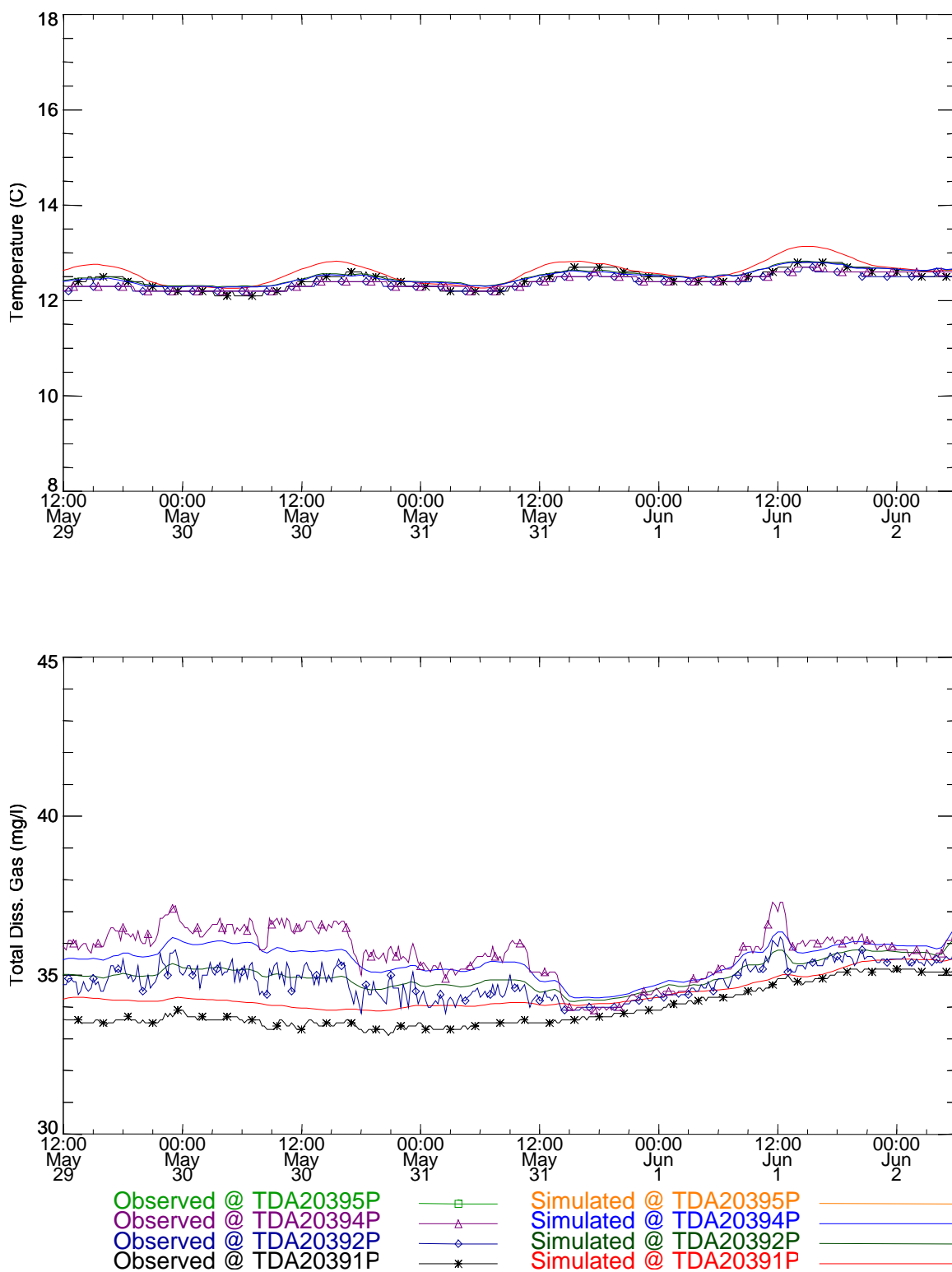


**Table 23. Statistical summary of measurements and simulations near river mile 209.2 during the Spring 1996 pool study (TM-BC).**

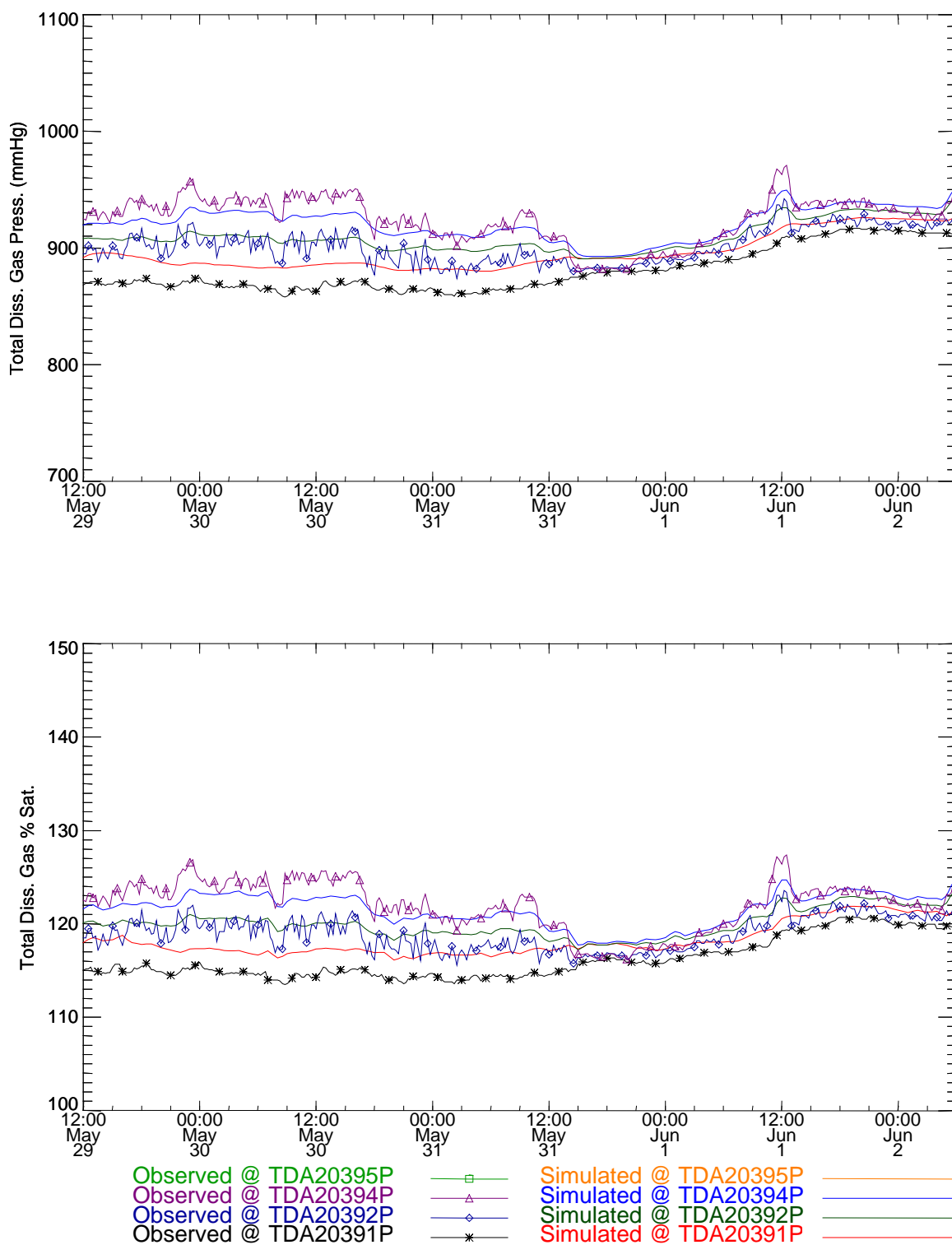
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA20923P	12.41	12.45	0.14	0.14	0.06
TDA20924P	12.44	12.45	0.15	0.14	0.03
Concentration					
TDA20923P	36.19	36.04	0.96	0.76	0.41
TDA20924P	36.52	36.41	1.02	0.92	0.36
Gas Pressure					
TDA20923P	937.39	934.72	23.74	19.15	9.93
TDA20924P	946.26	944.26	25.37	22.94	9.05
% Saturation					
TDA20923P	123.67	123.33	3.17	2.53	1.32
TDA20924P	124.84	124.59	3.38	3.08	1.21

**Table 24. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 209.2 during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA20923P	100	98.9	100	100
TDA20924P	100	99.45	99.45	99.45



**Figure 70. Temperature and total dissolved gas time series near Columbia River Mile 203.9 for the Spring 1996 pool study (TM-BC).**



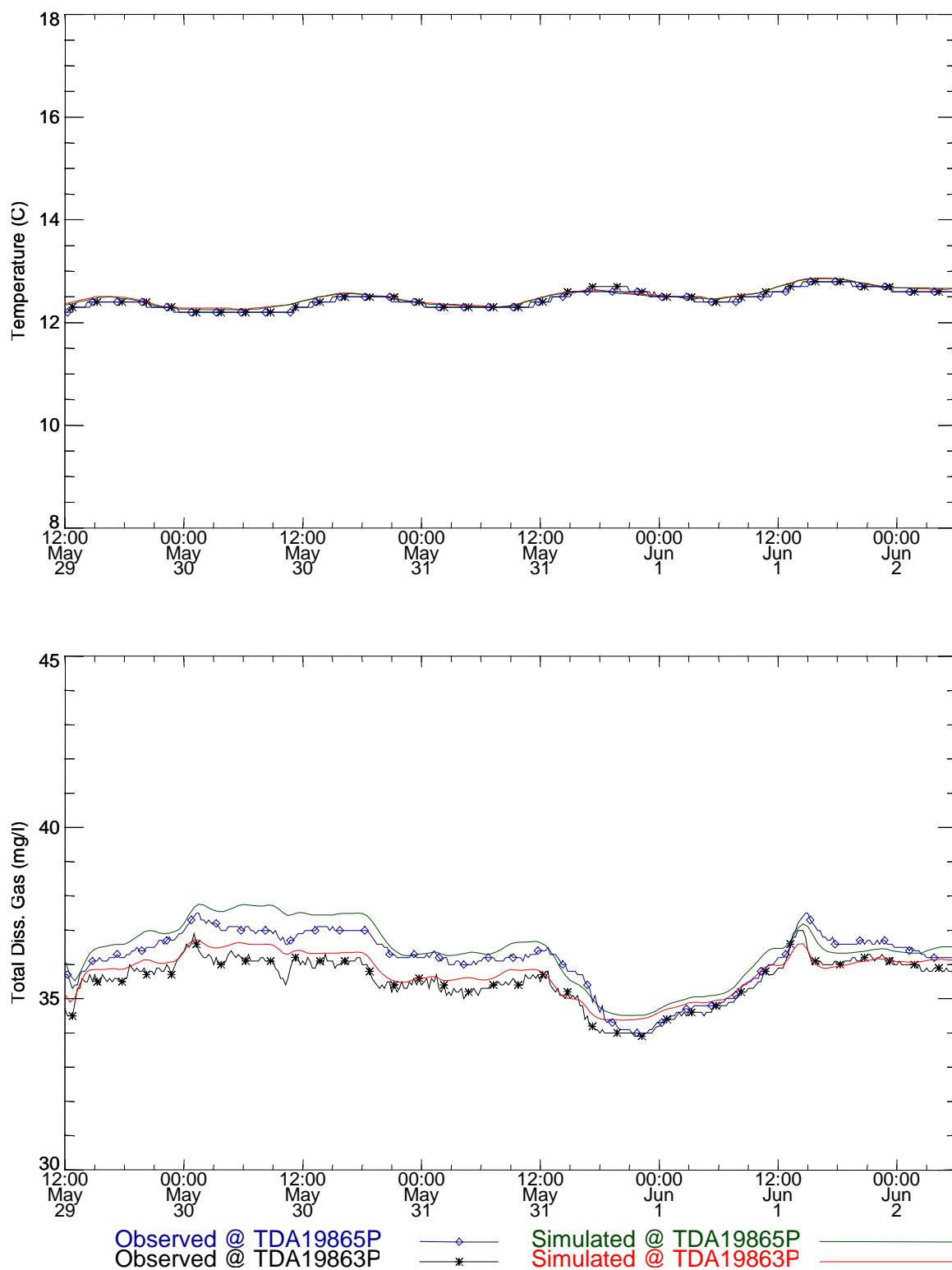
**Figure 71. Total dissolved gas time series comparisons near Columbia River Mile 203.9 for the Spring 1996 pool study (TM-BC).**

**Table 25. Statistical summary of measurements and simulations near river mile 203.9 during the Spring 1996 pool study (TM-BC).**

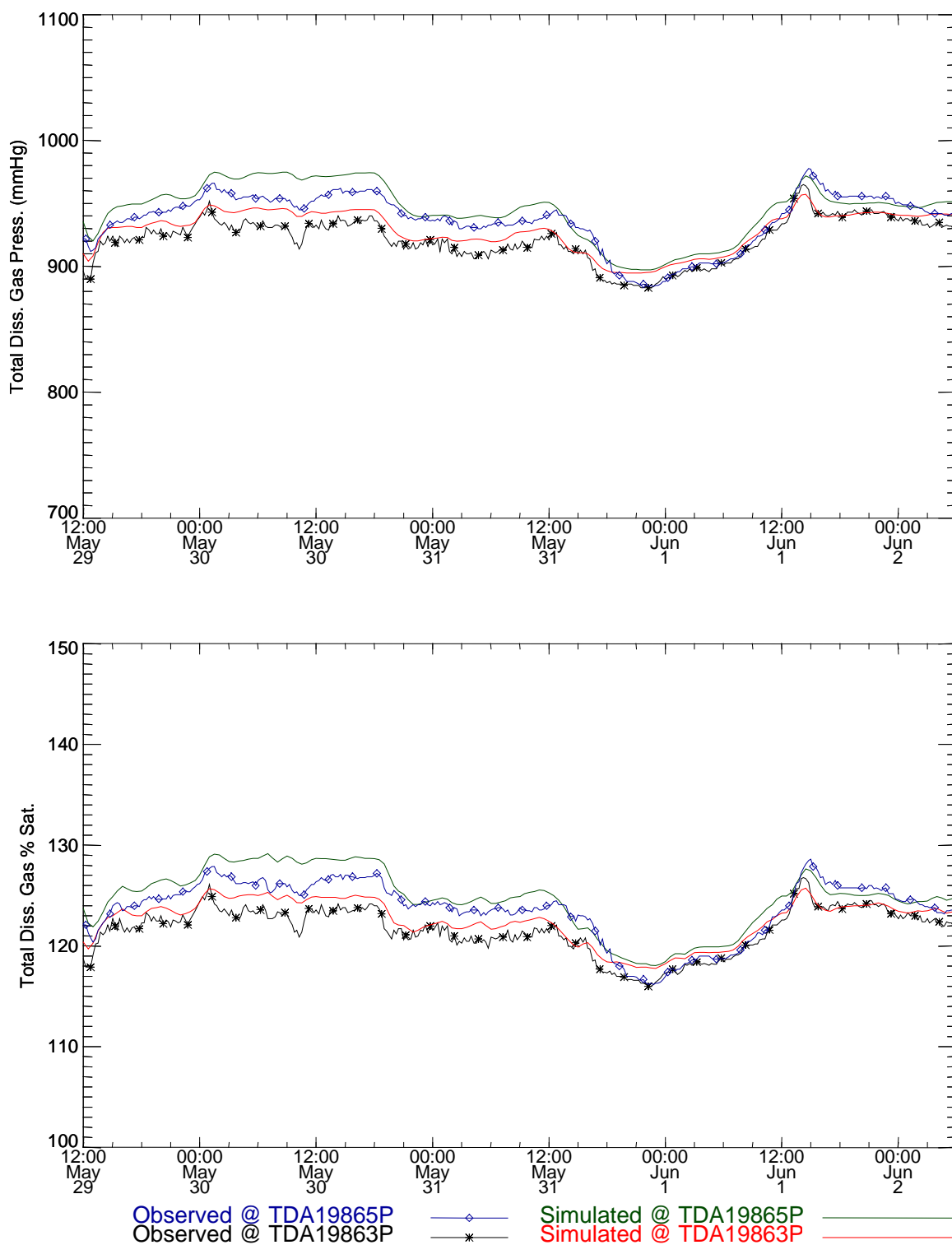
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA20391P	12.44	12.61	0.19	0.23	0.19
TDA20392P	12.37	12.51	0.14	0.15	0.14
TDA20394P	12.39	12.5	0.15	0.15	0.11
Concentration					
TDA20391P	33.95	34.41	0.64	0.5	0.5
TDA20392P	34.83	35.01	0.54	0.45	0.3
TDA20394P	35.71	35.46	0.8	0.53	0.45
Gas Pressure					
TDA20391P	880.66	896.11	18.69	15.21	16.2
TDA20392P	901.84	909.51	14.88	12.82	9.93
TDA20394P	924.71	920.95	19.91	14.05	10.06
% Saturation					
TDA20391P	116.18	118.23	2.16	1.71	2.15
TDA20392P	118.98	120	1.8	1.49	1.33
TDA20394P	122	121.51	2.66	1.79	1.35

**Table 26. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 203.9 during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA20391P	100	100	100	100
TDA20392P	100	100	100	100
TDA20394P	100	98.9	100	100



**Figure 72. Temperature and total dissolved gas time series near Columbia River Mile 198.6 for the Spring 1996 pool study (TM-BC).**



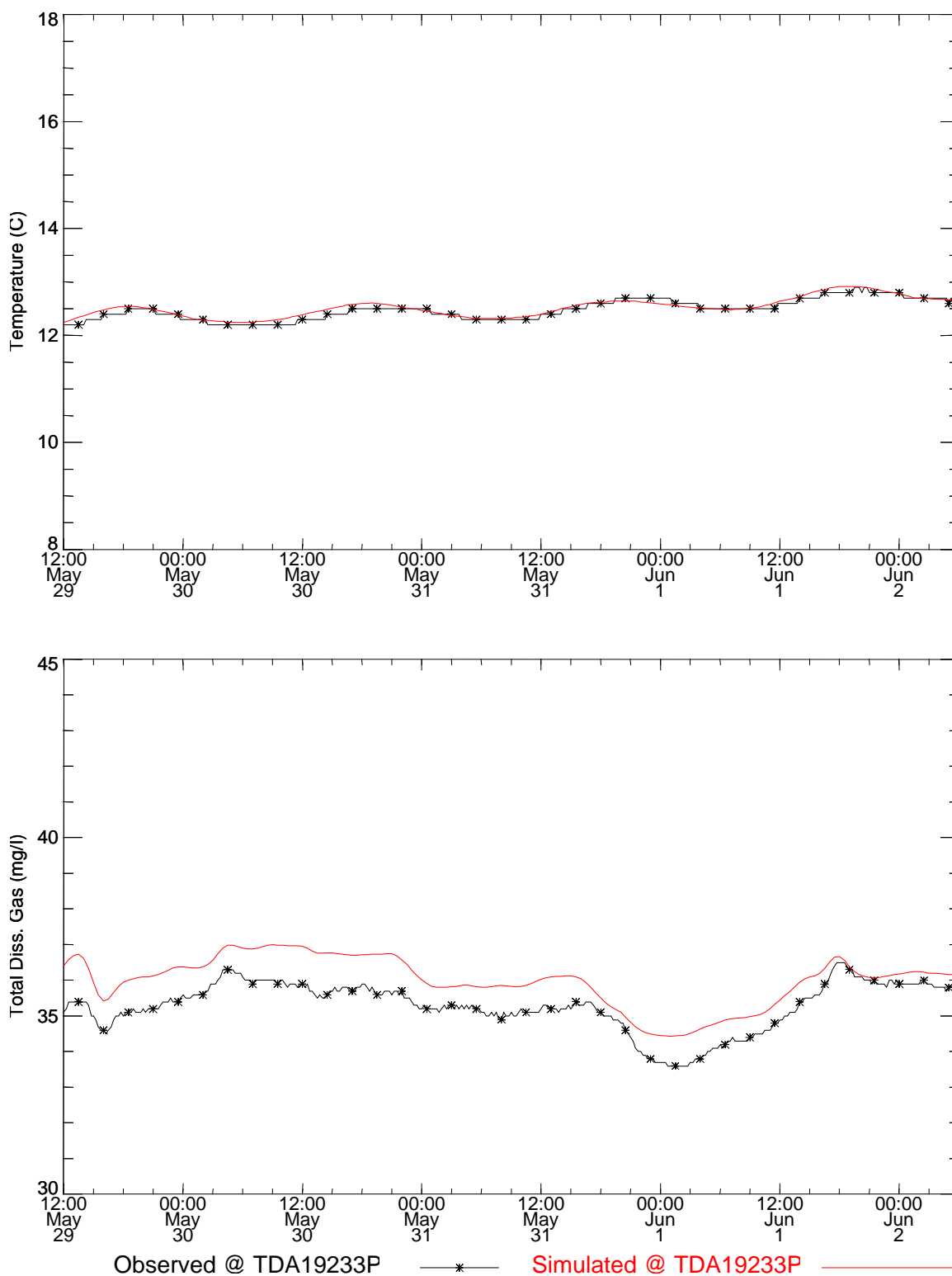
**Figure 73. Total dissolved gas time series comparisons near Columbia River Mile 198.6 for the Spring 1996 pool study (TM-BC).**

**Table 27. Statistical summary of measurements and simulations near river mile 198.6 during the Spring 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA19863P	12.46	12.51	0.17	0.16	0.07
TDA19865P	12.44	12.5	0.17	0.16	0.07
Concentration					
TDA19863P	35.53	35.76	0.69	0.63	0.3
TDA19865P	36.15	36.39	0.86	0.89	0.37
Gas Pressure					
TDA19863P	921.34	928.68	17.52	16.05	8.85
TDA19865P	937.16	944.81	21.6	22.11	10.71
% Saturation					
TDA19863P	121.55	122.53	2.31	2.15	1.21
TDA19865P	123.64	124.66	2.95	3.04	1.45

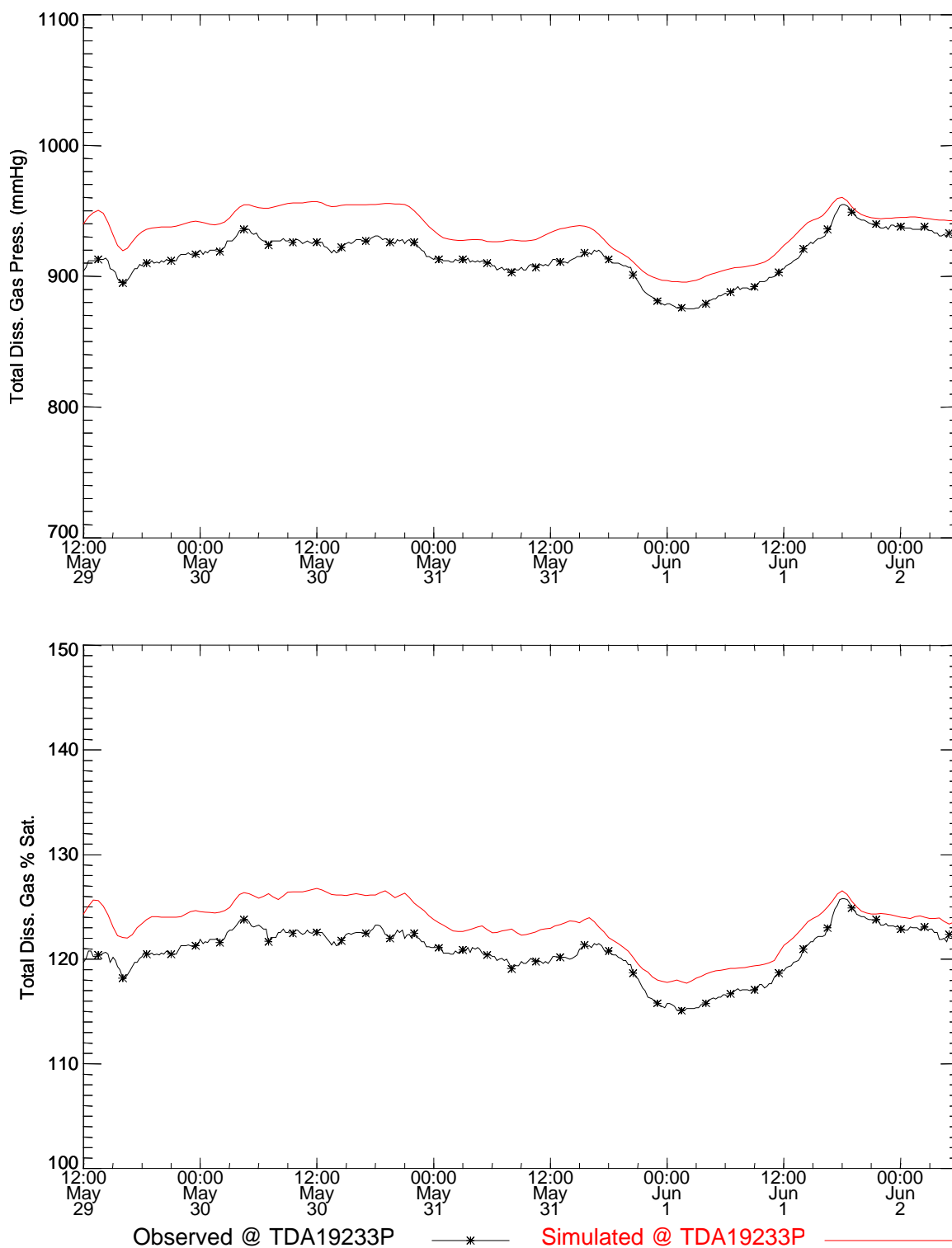
**Table 28. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 198.6 during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA19863P	100	100	100	100
TDA19865P	100	100	100	100



**Figure 74. Temperature and total dissolved gas time series near Columbia River Mile 192.3 during the Spring 1996 pool study (TM-BC).**





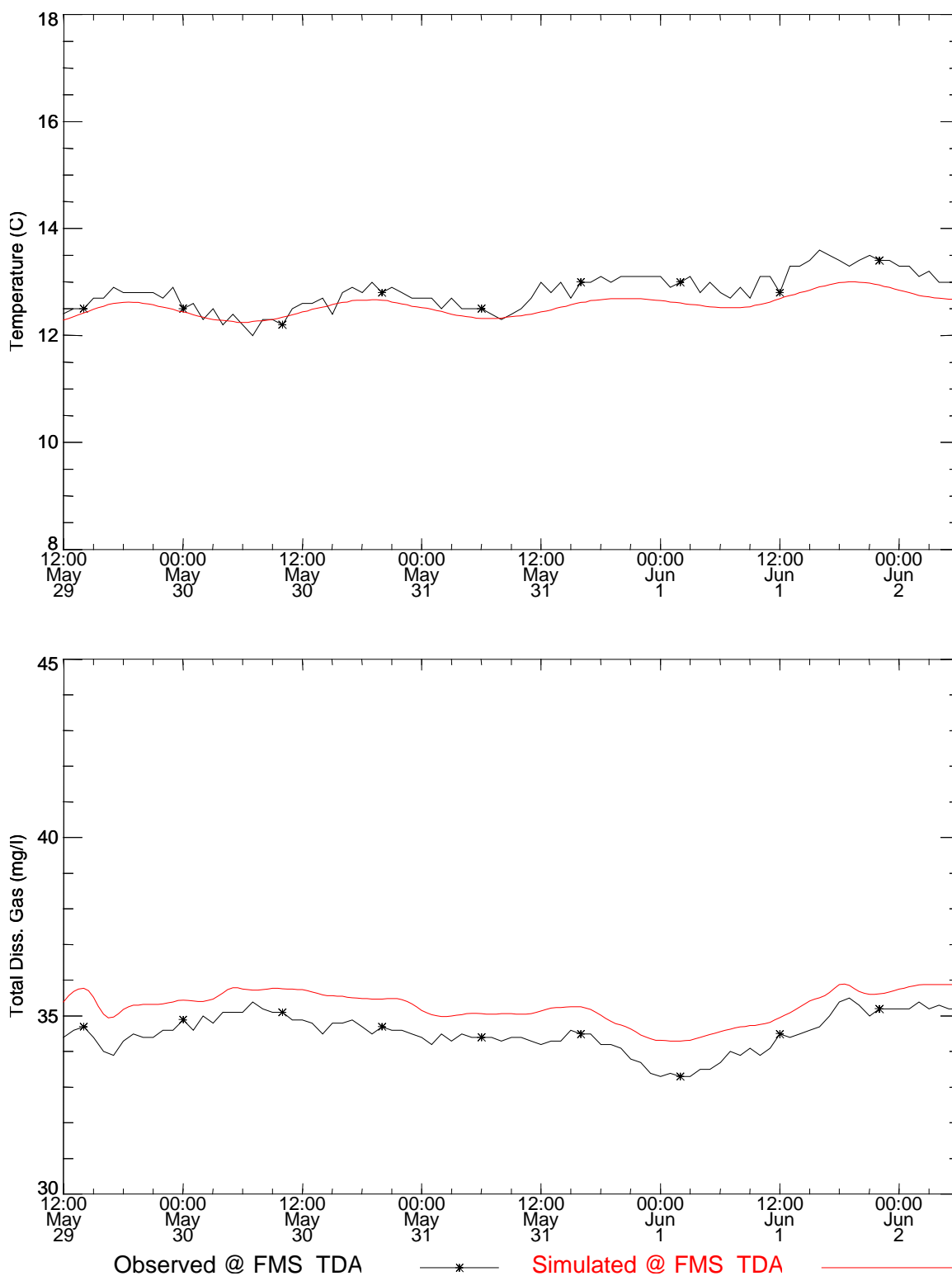
**Figure 75. Total dissolved gas time series comparisons near Columbia River Mile 192.3 during the Spring 1996 pool study (TM-BC).**

**Table 29. Statistical summary of measurements and simulations near river mile 192.3 during the Spring 1996 pool study (TM-BC).**

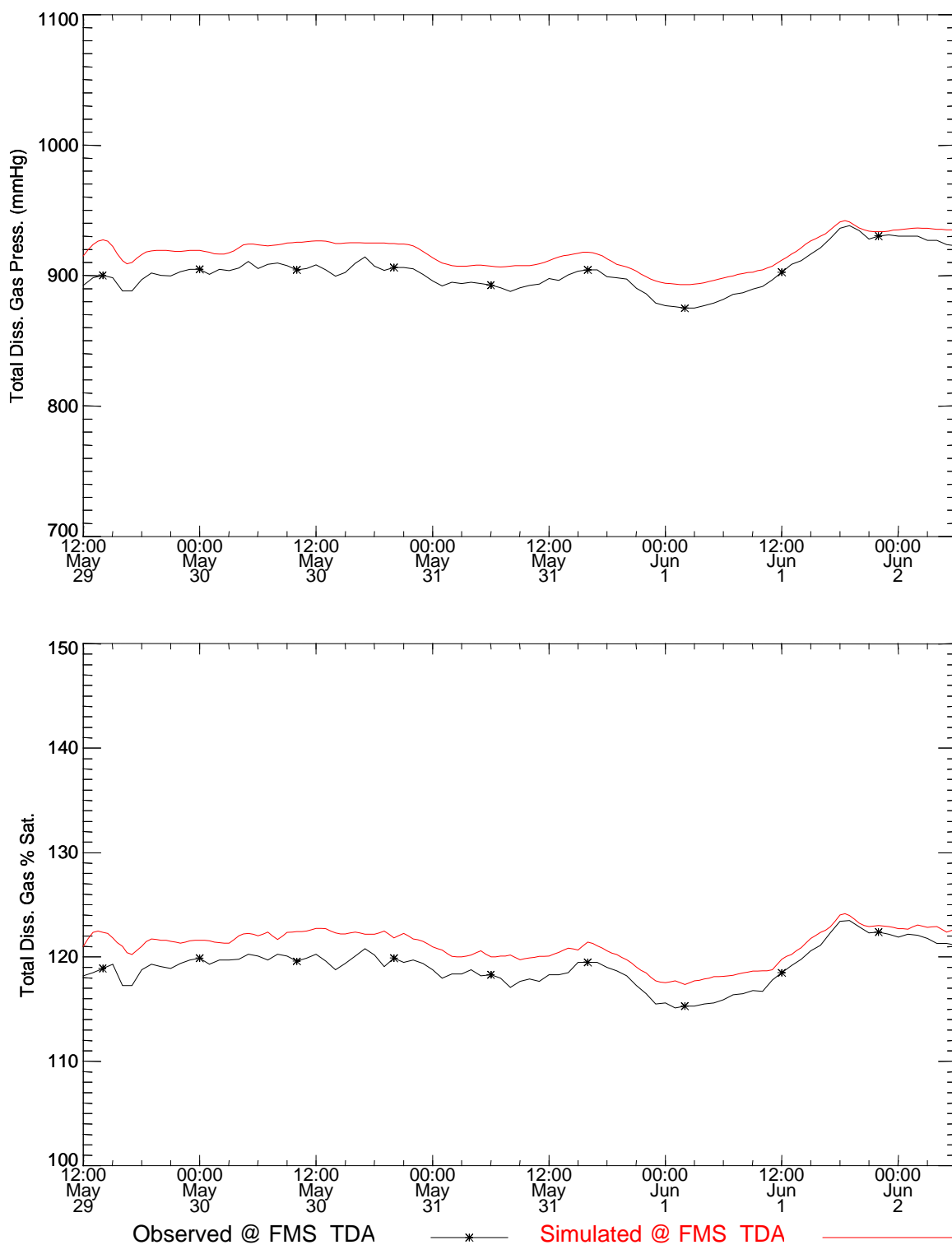
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA19233P	12.48	12.52	0.19	0.17	0.07
Concentration					
TDA19233P	35.28	35.99	0.68	0.7	0.77
Gas Pressure					
TDA19233P	915.24	935	17.43	17.61	21.18
% Saturation					
TDA19233P	120.75	123.37	2.35	2.46	2.81

**Table 30. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 192.3 during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA19233P	100	87.85	100	98.9



**Figure 76. Temperature and total dissolved gas time series at the TDA fixed monitor during the Spring 1996 pool study (TM-BC).**



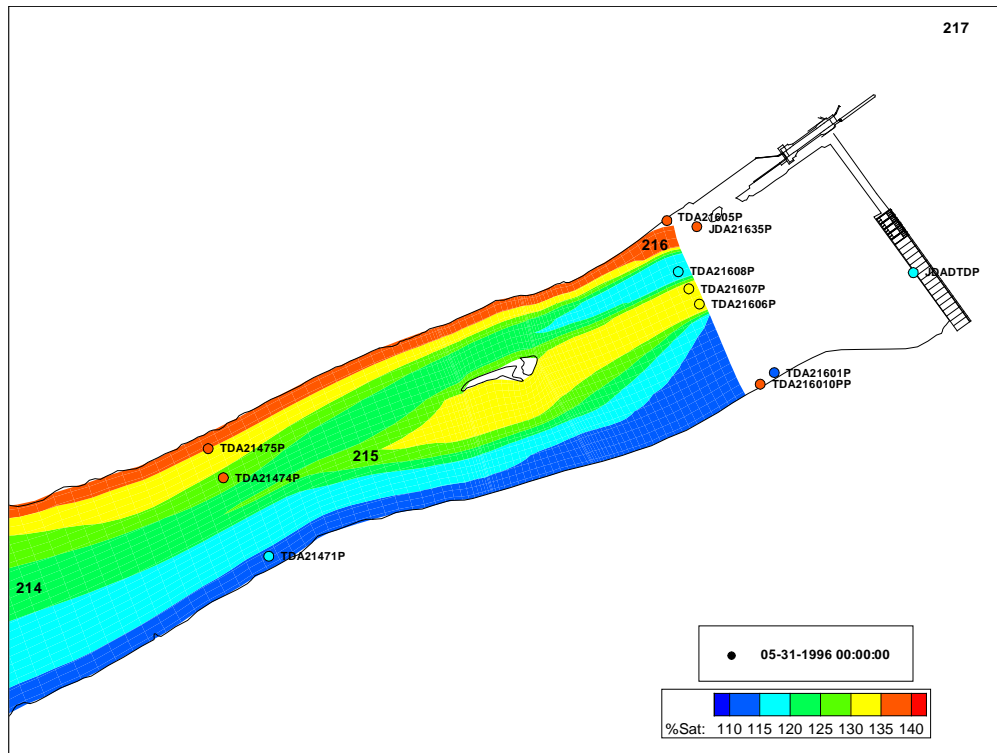
**Figure 77. Total dissolved gas time series comparisons at the TDA fixed monitor during the Spring 1996 pool study (TM-BC).**

**Table 31. Statistical summary of measurements and simulations at the TDA fixed monitor during the Spring 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_TDA	12.83	12.57	0.34	0.19	0.31
Concentration					
FMS_TDA	34.52	35.27	0.53	0.44	0.77
Gas Pressure					
FMS_TDA	902.79	917.46	14.82	12.17	15.58
% Saturation					
FMS_TDA	119.1	121.05	1.9	1.62	2.08

**Table 32. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the TDA fixed monitor during the Spring 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_TDA	100	92.82	100	100

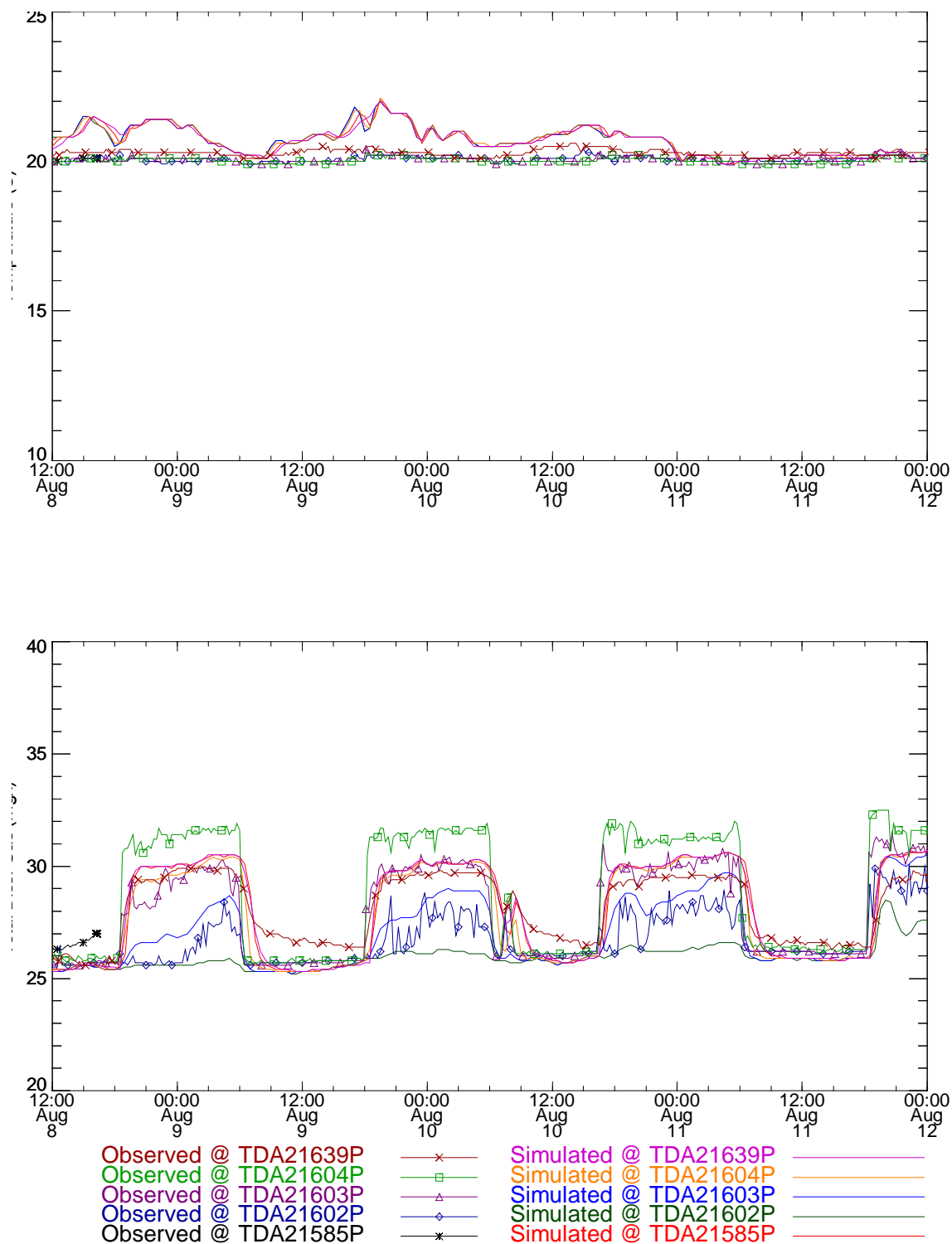


**Figure 78. Spatial distribution of dissolved gas near Columbia river mile 216 during the Spring 1996 study period.**

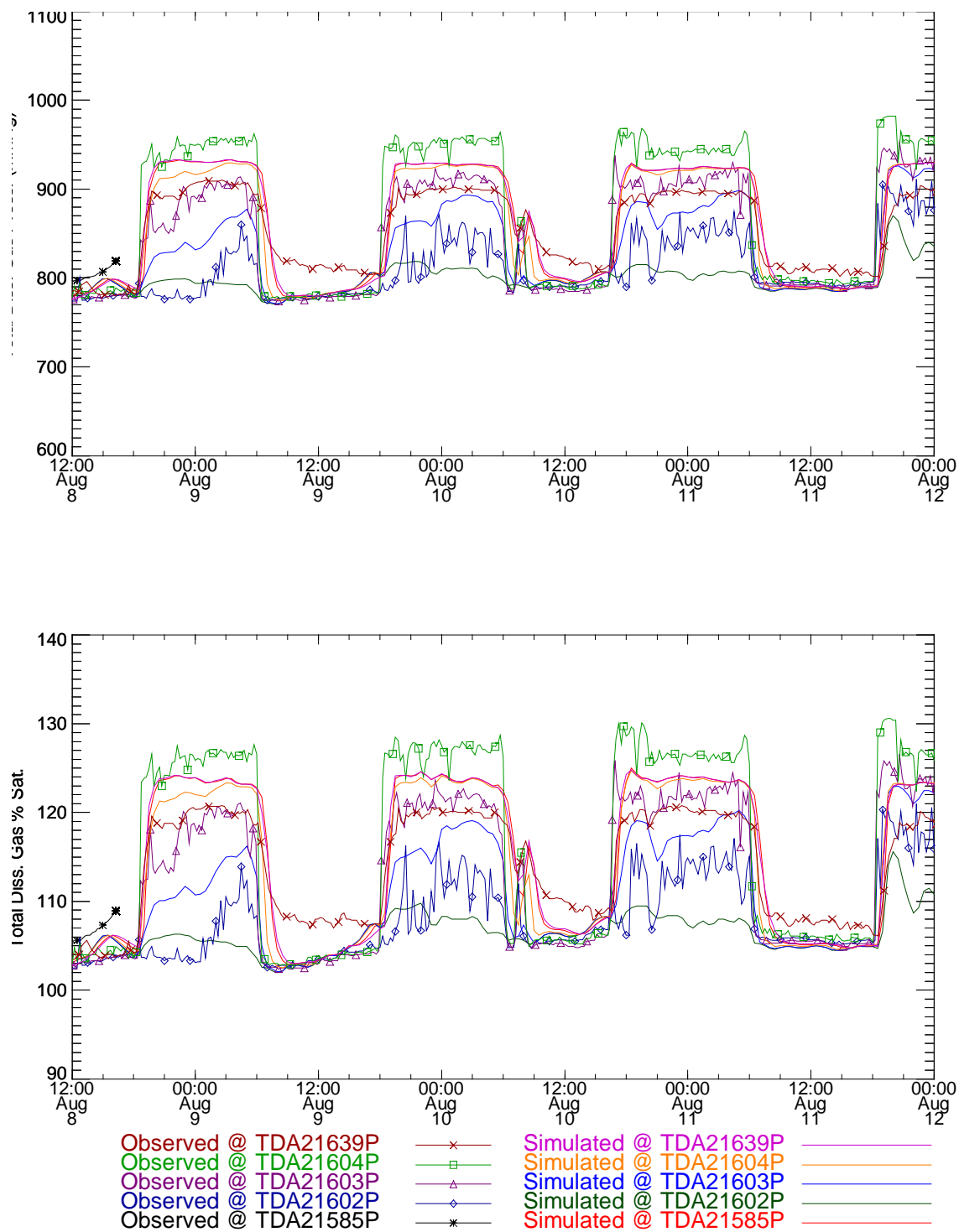
#### ***1.4.2 1996 Summer Simulation***

##### **Boundary Conditions using John Day Sourcing Function and Forebay FMS Data**

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.



**Figure 79. Temperature and total dissolved gas time series near Columbia River Mile 216.0 during the Summer 1996 pool study (FMS-BC).**



**Figure 80. Total dissolved gas time series comparisons near Columbia River Mile 216.0 during the Summer 1996 pool study (FMS-BC).**

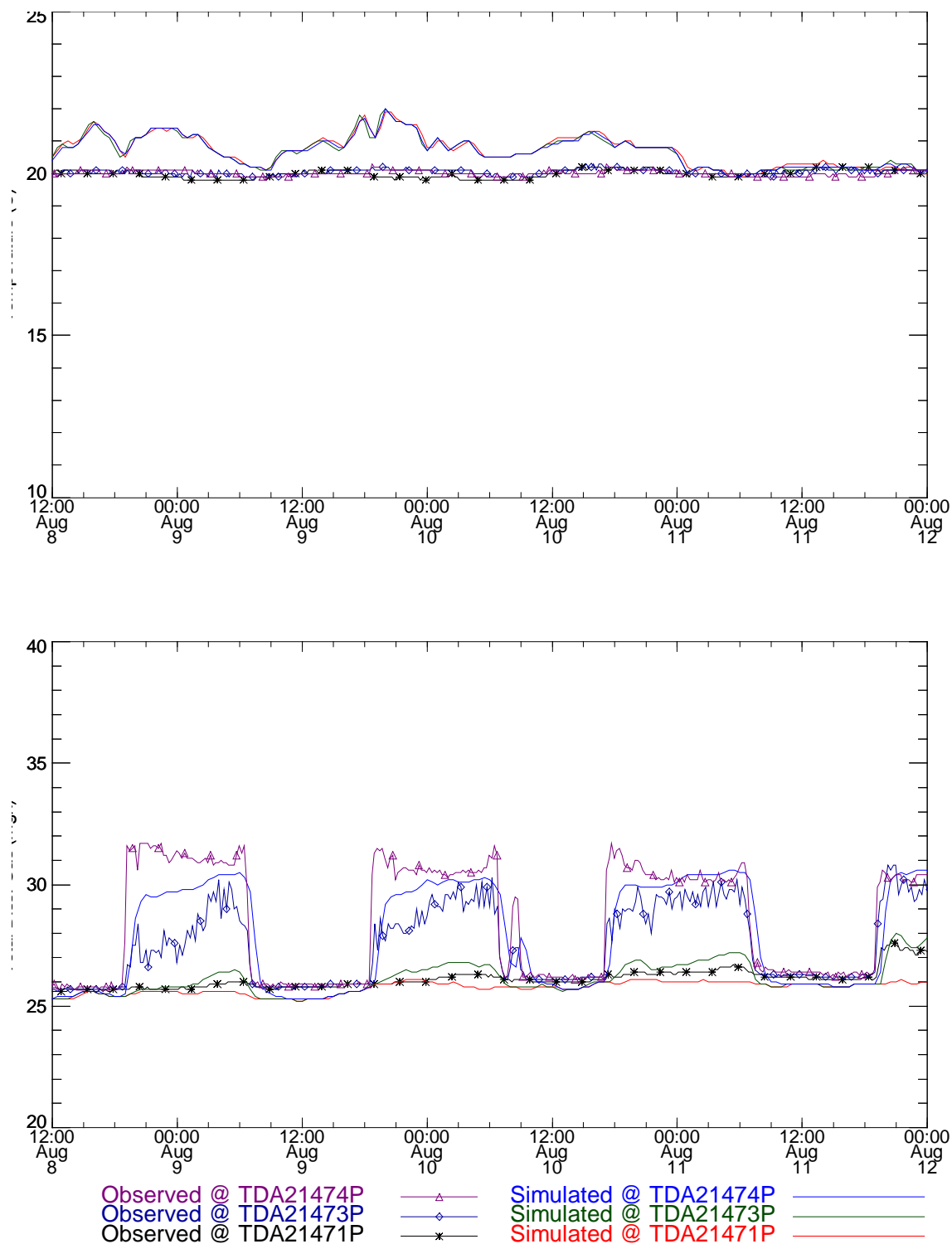


**Table 33. Statistical summary of measurements and simulations near river mile 216.0 during the Summer 1996 pool study (FMS-BC).**

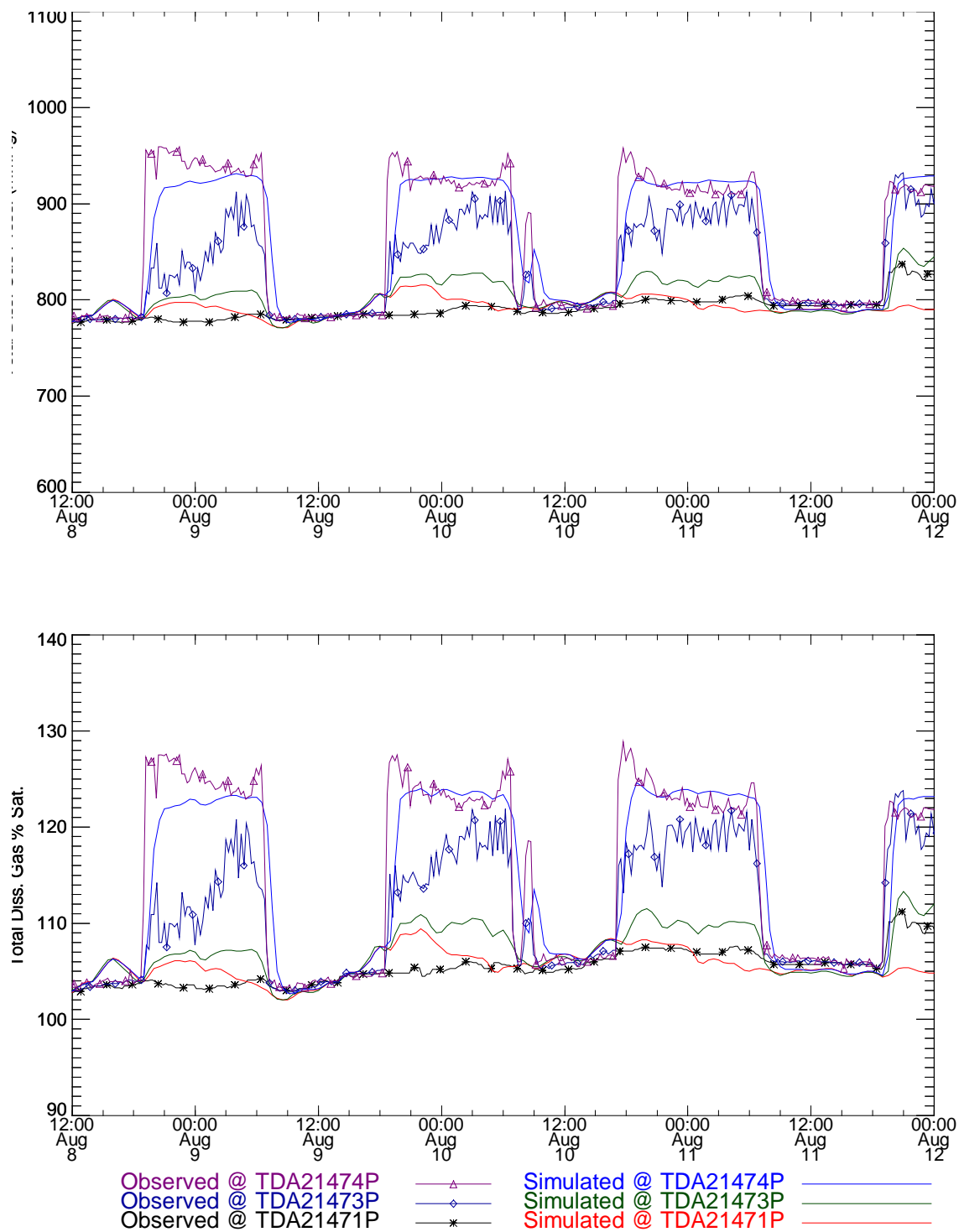
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA21585P	20.10	20.67	0.02	0.48	0.75
TDA21602P	20.07	20.69	0.09	0.48	0.77
TDA21603P	20.05	20.69	0.09	0.48	0.78
TDA21604P	20.02	20.69	0.09	0.48	0.80
TDA21639P	20.28	20.67	0.11	0.47	0.58
Concentration (mg/l)					
TDA21585P	26.98	28.04	0.11	2.16	2.39
TDA21602P	26.73	25.94	1.14	0.56	1.10
TDA21603P	27.95	27.02	2.01	1.57	1.29
TDA21604P	28.81	27.89	2.68	2.13	1.40
TDA21639P	28.10	28.08	1.48	2.15	0.79
Gas Pressure (mmHg)					
TDA21585P	818.19	861.42	3.71	65.22	77.54
TDA21602P	810.34	798.49	34.23	15.99	28.25
TDA21603P	846.17	830.71	60.69	45.95	29.55
TDA21604P	871.41	856.90	80.69	64.30	34.16
TDA21639P	854.23	862.60	43.59	64.68	25.92
% Saturation					
TDA21585P	108.78	114.77	0.54	8.84	10.57
TDA21602P	107.99	106.38	4.66	2.31	3.78
TDA21603P	112.78	110.68	8.23	6.27	3.96
TDA21604P	116.14	114.17	10.87	8.72	4.56
TDA21639P	113.85	114.93	5.94	8.77	3.46

**Table 34. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 216.0 during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA21585P	81.66	13.02	43.20	42.01
TDA21602P	82.25	66.27	77.51	78.11
TDA21603P	78.70	59.76	82.25	82.25
TDA21604P	79.29	58.58	88.17	87.57
TDA21639P	91.12	81.66	92.90	91.72



**Figure 81. Temperature and total dissolved gas time series near Columbia River Mile 214.7 during the Summer 1996 pool study (FMS-BC).**



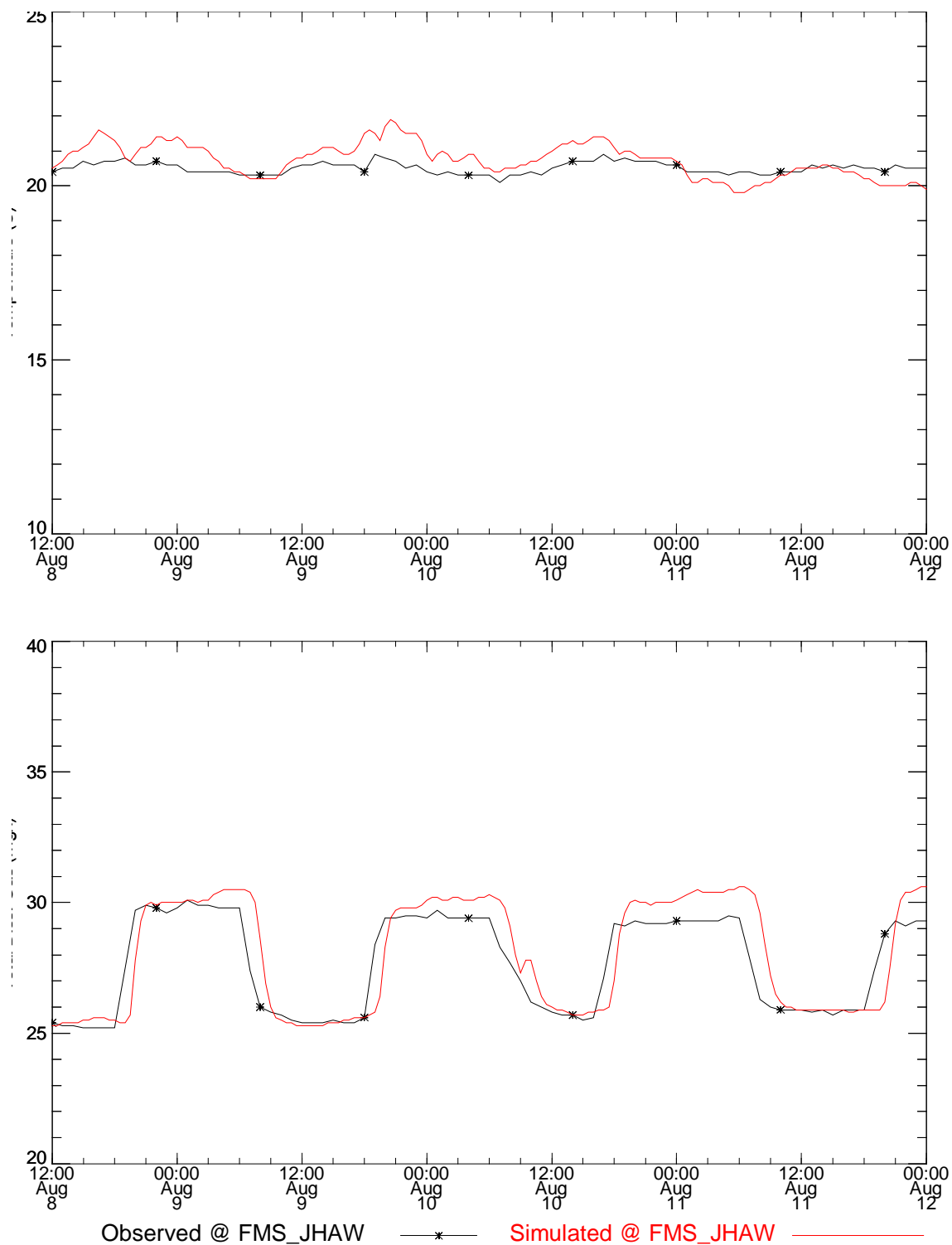
**Figure 82. Total dissolved gas time series comparisons near Columbia River Mile 214.7 during the Summer 1996 pool study (FMS-BC).**

**Table 35. Statistical summary of measurements and simulations near river mile 214.7 during the Summer 1996 pool study (FMS-BC).**

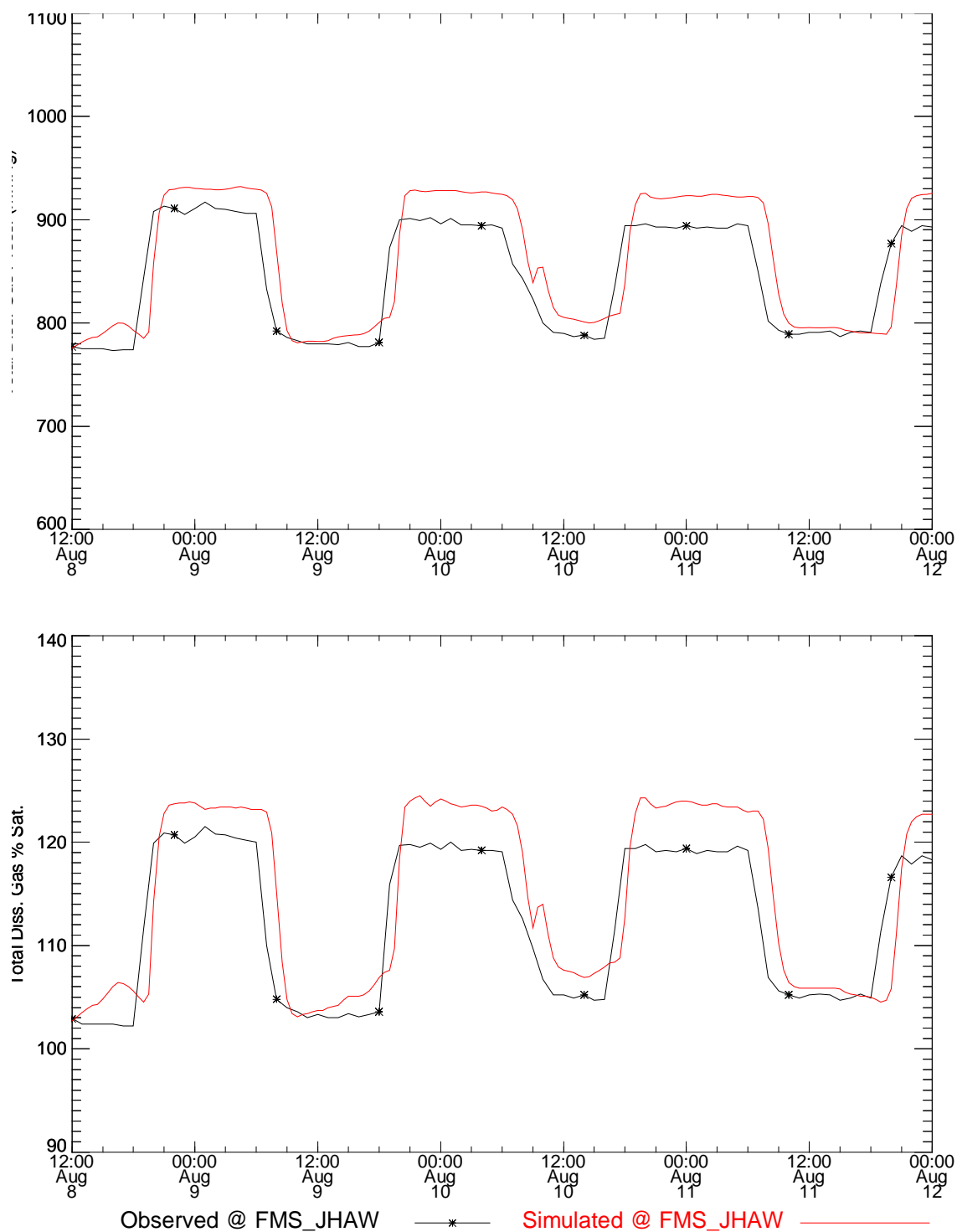
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA21471P	19.99	20.72	0.12	0.48	0.89
TDA21473P	20.05	20.70	0.08	0.48	0.79
TDA21474P	20.01	20.70	0.08	0.47	0.81
Concentration (mg/l)					
TDA21471P	26.11	25.74	0.40	0.25	0.47
TDA21473P	27.50	26.11	1.58	0.63	1.75
TDA21474P	28.48	27.91	2.30	2.13	1.20
Gas Pressure (mmHg)					
TDA21471P	790.66	792.93	12.09	9.12	14.42
TDA21473P	832.62	803.70	47.15	18.02	43.56
TDA21474P	861.28	857.88	68.77	64.00	29.78
% Saturation					
TDA21471P	105.37	105.64	1.74	1.57	1.91
TDA21473P	110.97	107.07	6.42	2.62	5.83
TDA21474P	114.79	114.30	9.29	8.68	3.98

**Table 36. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 214.7 during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA21471P	72.19	94.08	98.22	98.22
TDA21473P	82.25	49.11	60.36	60.36
TDA21474P	80.47	77.51	88.17	88.17



**Figure 83. Temperature and total dissolved gas time series at the JHAW fixed monitor during the Summer 1996 pool study (FMS-BC).**



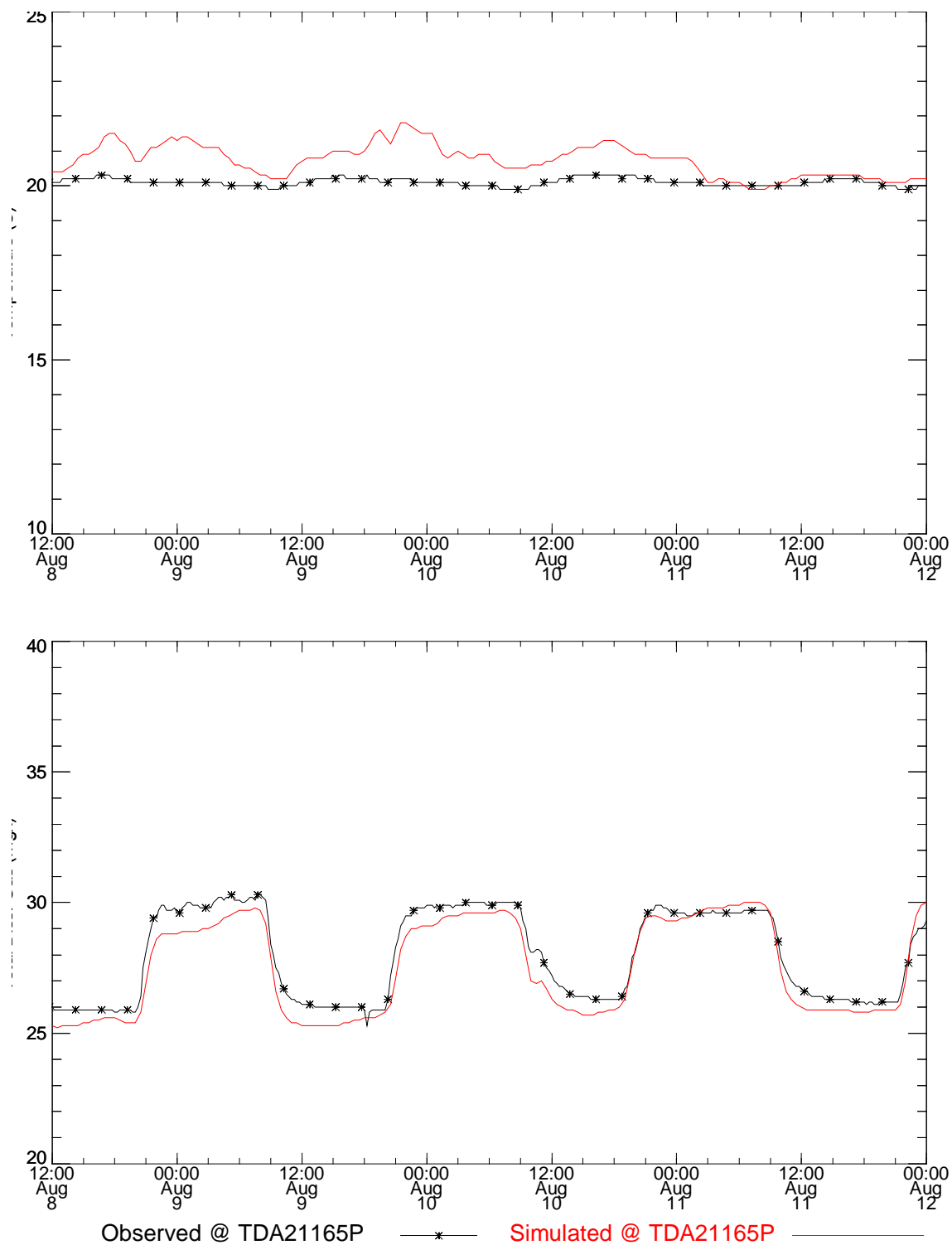
**Figure 84. Total dissolved gas time series comparisons at the JHAW fixed monitor during the Summer 1996 pool study (FMS-BC).**

**Table 37. Statistical summary of measurements and simulations at the JHAW fixed monitor during the Summer 1996 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_JHAW	20.51	20.74	0.16	0.48	0.47
Concentration (mg/l)					
FMS_JHAW	27.66	28.00	1.80	2.14	1.06
Gas Pressure (mmHg)					
FMS_JHAW	844.60	860.83	53.75	62.84	33.04
% Saturation					
FMS_JHAW	112.25	114.69	7.26	8.50	4.50

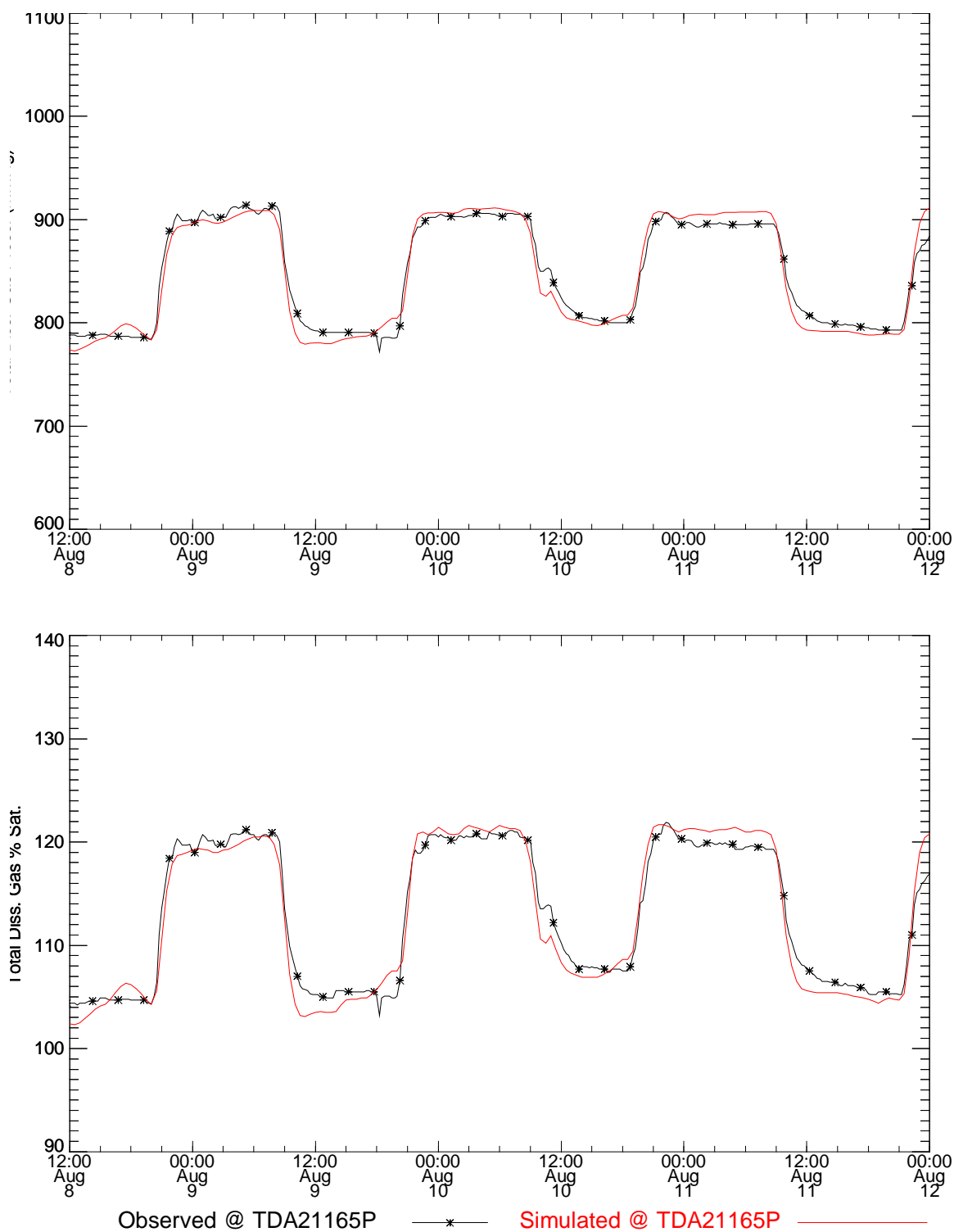
**Table 38. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the JHAW fixed monitor during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_JHAW	98.22	74.56	84.62	84.02



**Figure 85. Temperature and total dissolved gas time series near Columbia River Mile 211.6 during the Summer 1996 pool study (FMS-BC).**





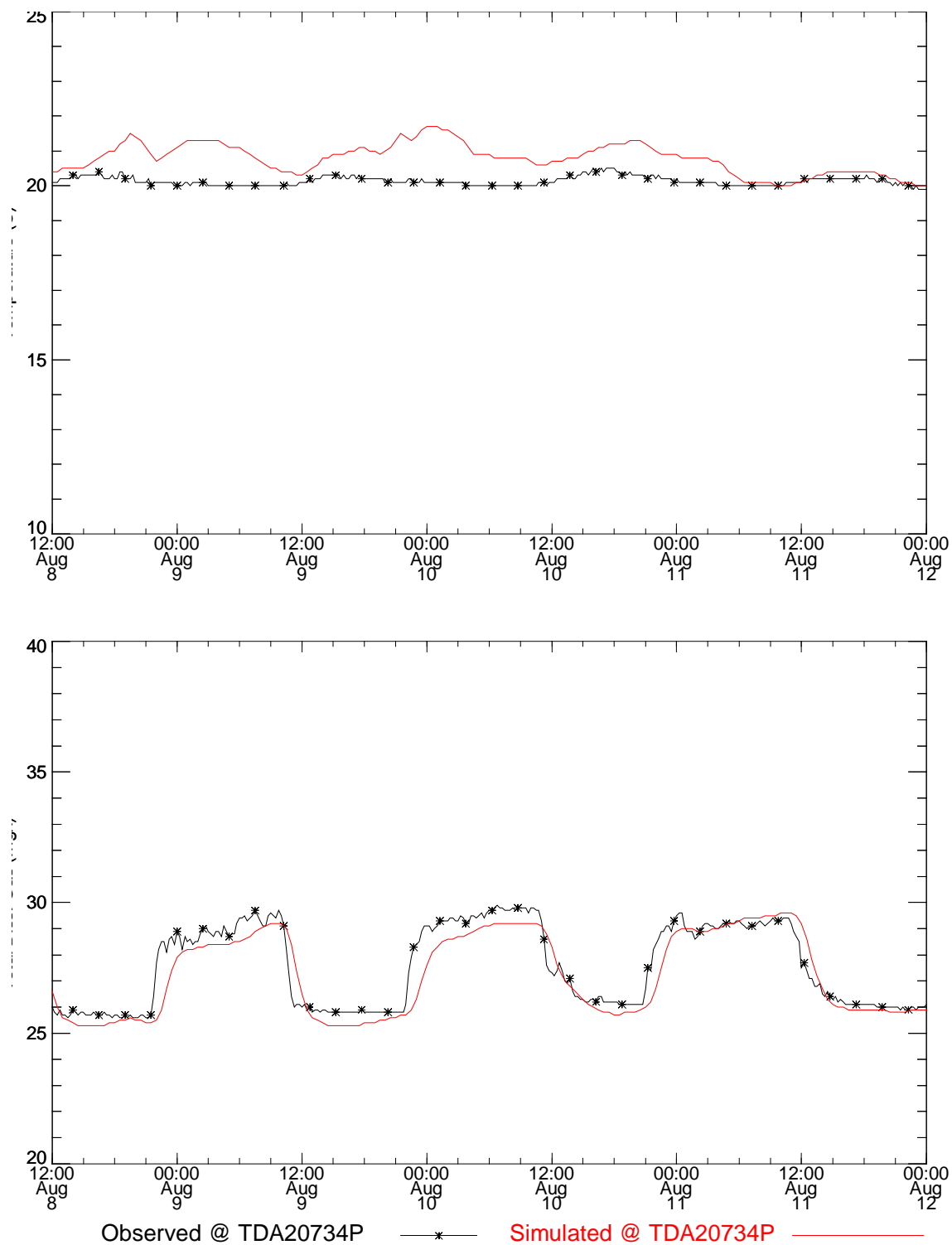
**Figure 86. Total dissolved gas time series comparisons near Columbia River Mile 211.6 during the Summer 1996 pool study (FMS-BC).**

**Table 39. Statistical summary of measurements and simulations near river mile 211.6 during the Spring 1996 pool study (FMS-BC).**

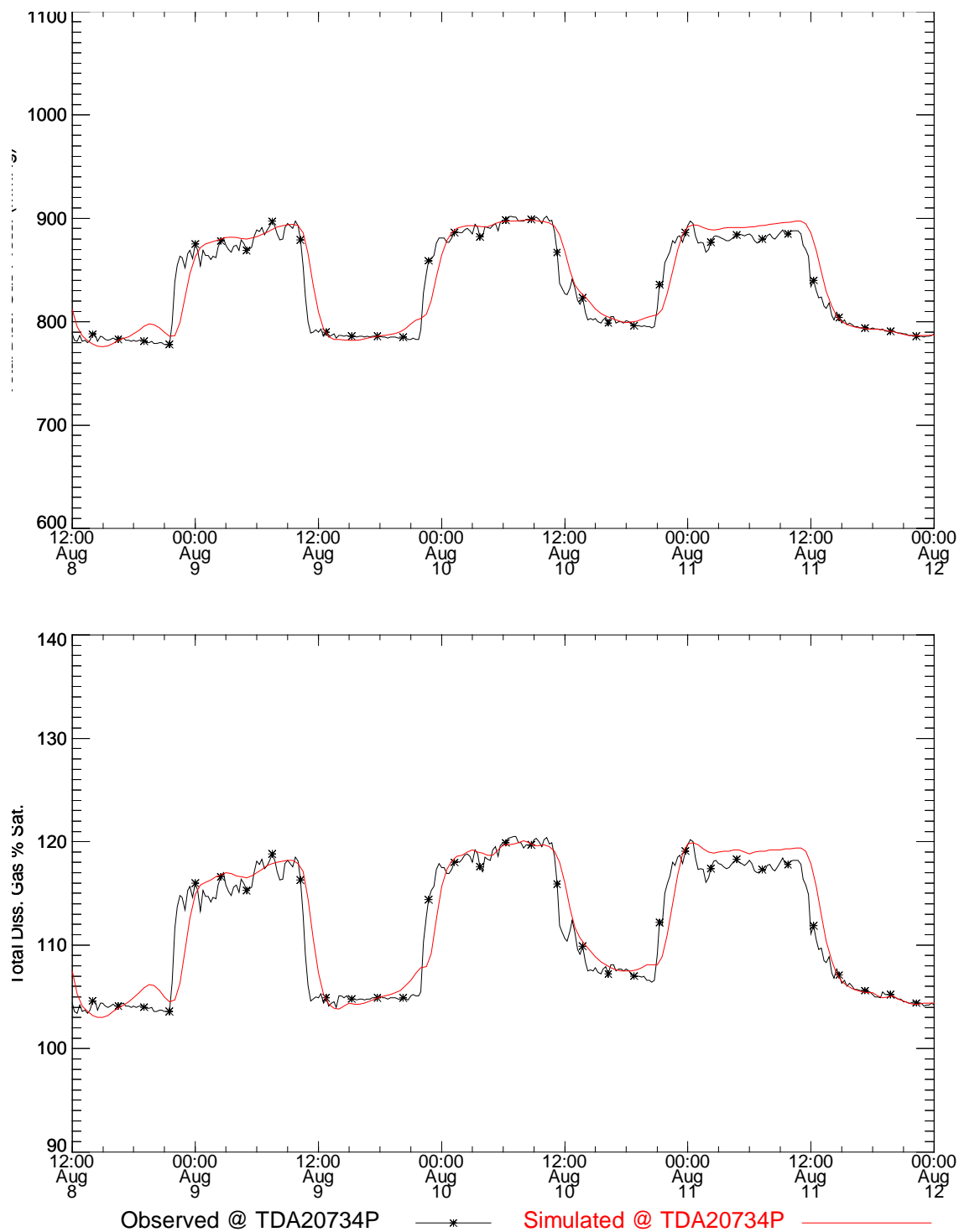
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA21165P	20.10	20.73	0.11	0.46	0.75
Concentration (mg/l)					
TDA21165P	27.99	27.51	1.72	1.81	0.61
Gas Pressure (mmHg)					
TDA21165P	847.76	846.31	50.12	54.06	10.54
% Saturation					
TDA21165P	112.99	112.75	6.71	7.31	1.47

**Table 40. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 211.6 during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA21165P	85.80	95.27	100	100



**Figure 87. Temperature and total dissolved gas time series near Columbia River Mile 207.3 during the Summer 1996 pool study (FMS-BC).**



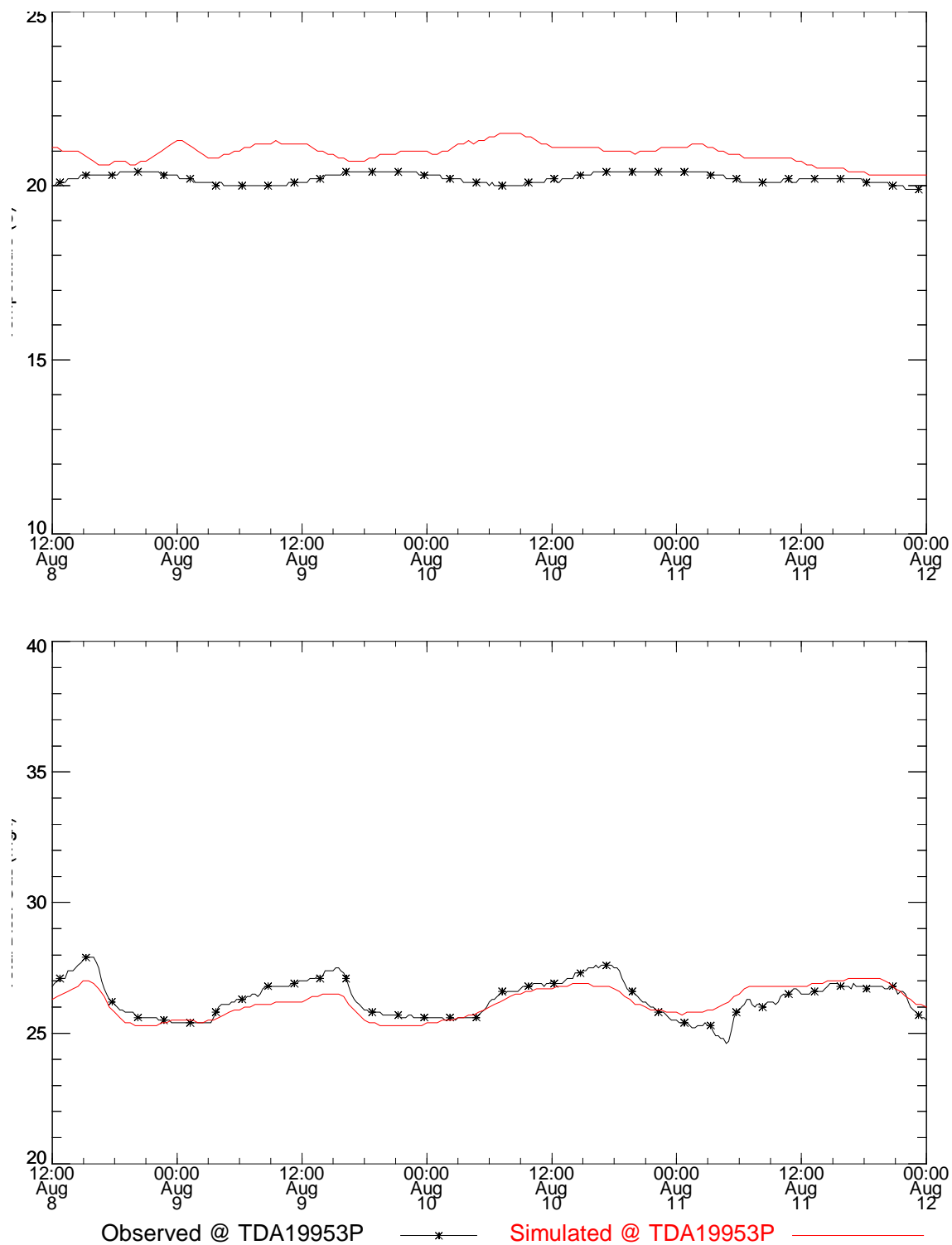
**Figure 88. Total dissolved gas time series comparisons near Columbia River Mile 207.3 during the Summer 1996 pool study (FMS-BC).**

**Table 41. Statistical summary of measurements and simulations near river mile 207.3 during the Summer 1996 pool study (FMS-BC).**

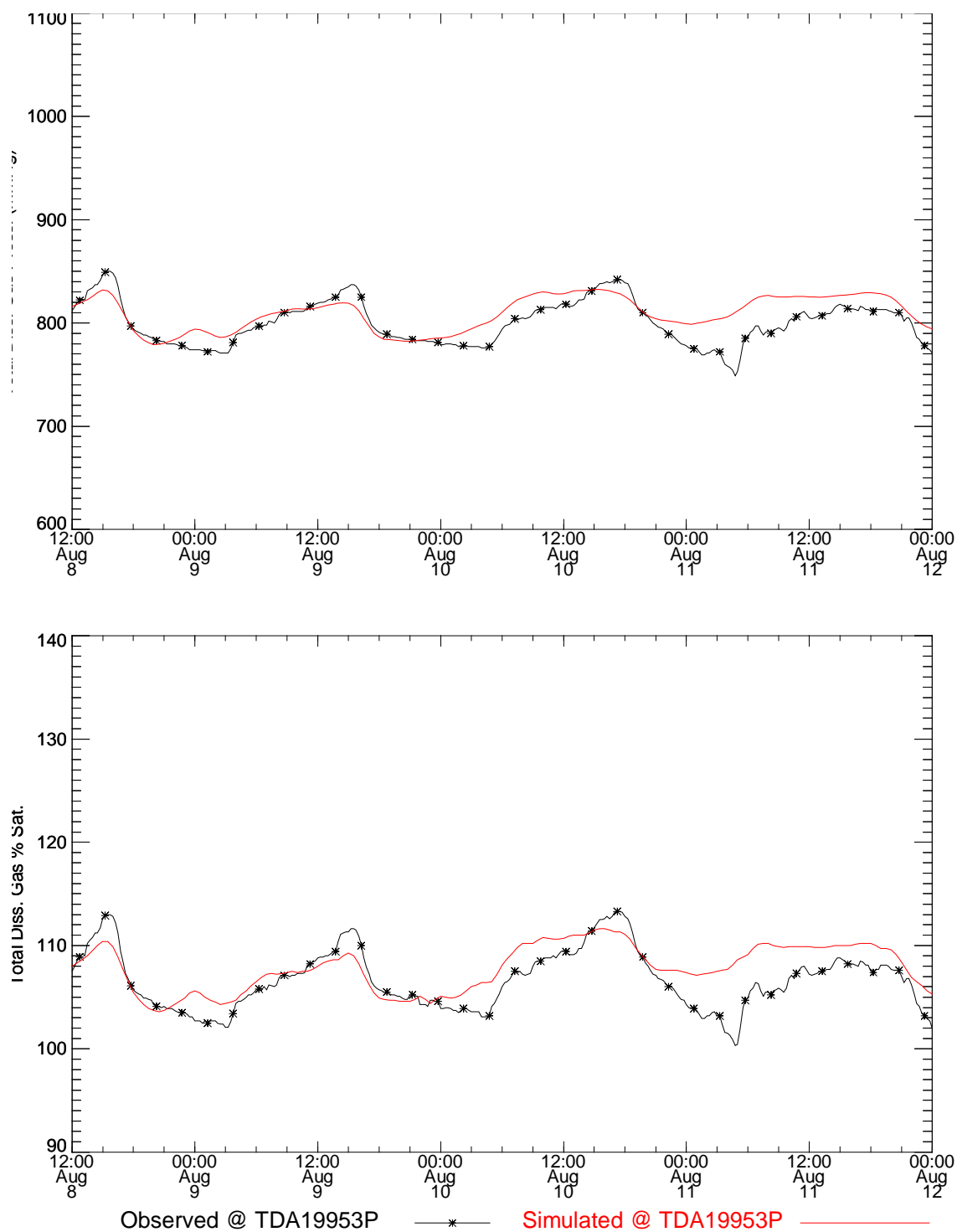
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA20734P	20.13	20.78	0.13	0.43	0.77
Concentration (mg/l)					
TDA20734P	27.54	27.25	1.57	1.57	0.67
Gas Pressure (mmHg)					
TDA20734P	835.18	839.15	45.50	46.63	15.99
% Saturation					
TDA20734P	111.30	111.80	6.09	6.24	2.13

**Table 42. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 207.3 during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA20734P	81.07	90.53	94.08	94.67



**Figure 89. Temperature and total dissolved gas time series near Columbia River Mile 195.5 during the Summer 1996 pool study (FMS-BC).**



**Figure 90. Total dissolved gas time series comparisons near Columbia River Mile 195.5 during the Summer 1996 pool study (FMS-BC).**

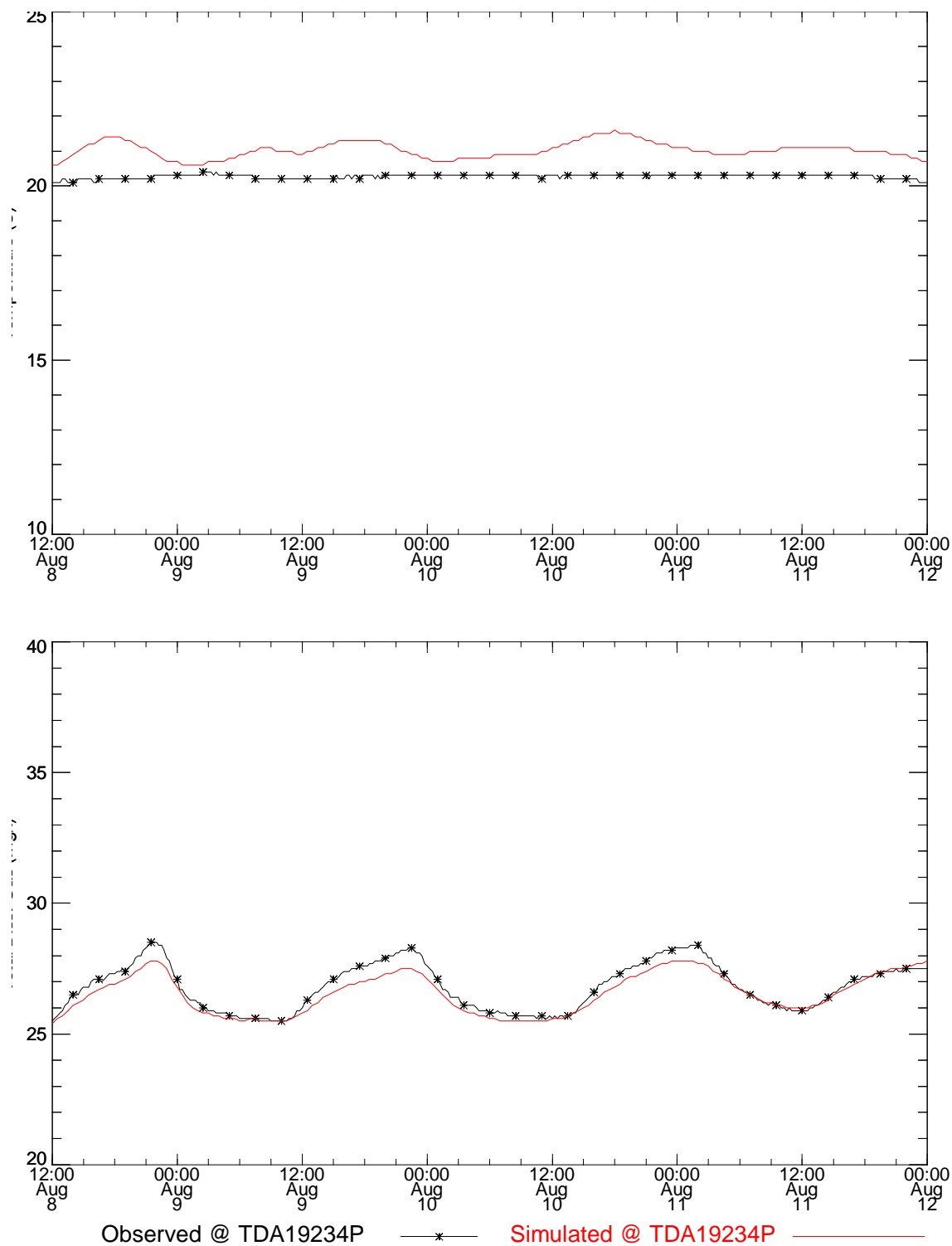
**Table 43. Statistical summary of measurements and simulations at river mile 195.5 during the Summer 1996 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA19953P	20.21	20.92	0.15	0.29	0.78
Concentration (mg/l)					
TDA19953P	26.32	26.19	0.72	0.57	0.48
Gas Pressure (mmHg)					
TDA19953P	800.14	809.37	21.12	16.44	16.97
% Saturation					
TDA19953P	106.63	107.82	2.87	2.24	2.28

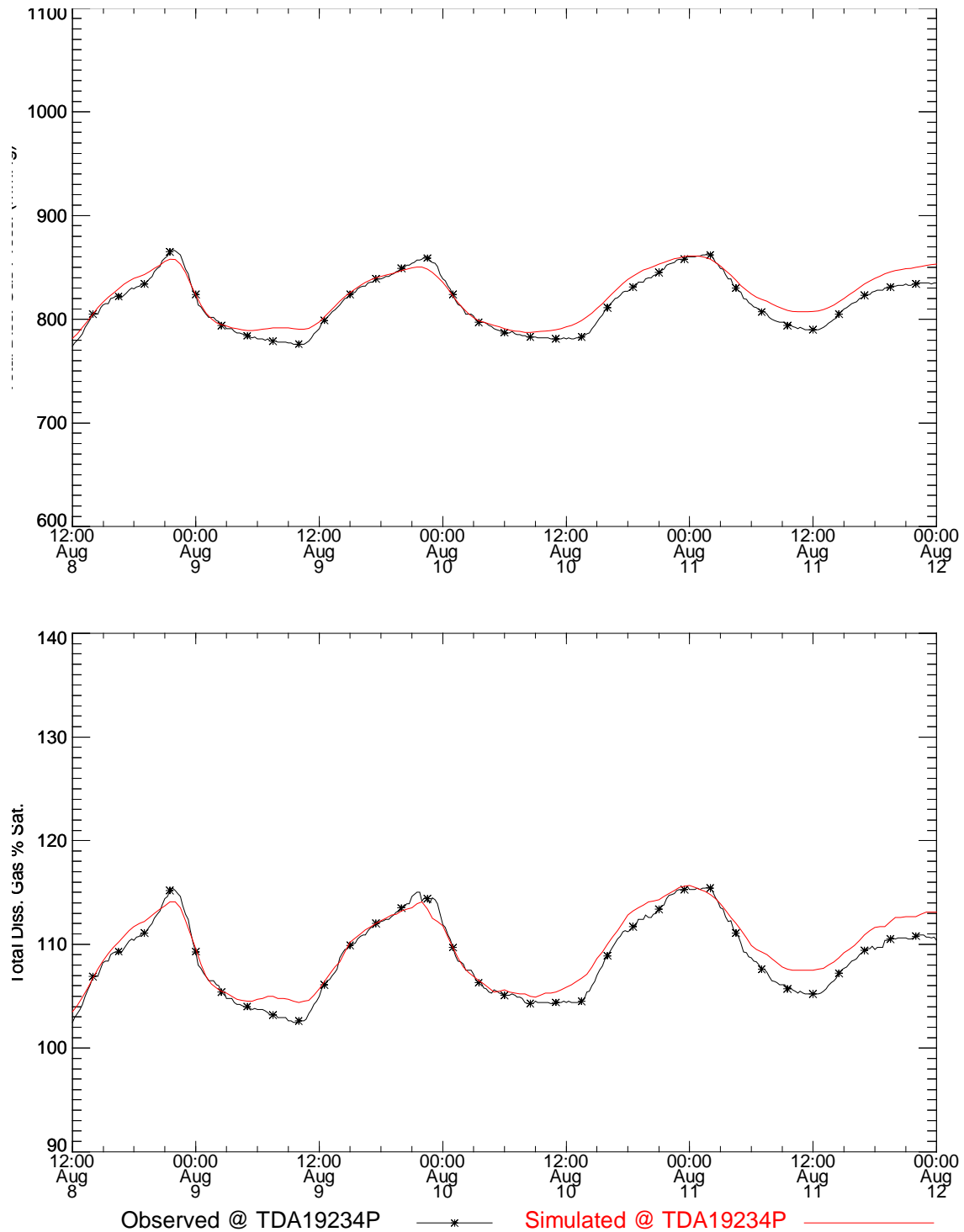
**Table 44. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 195.5 during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA19953P	81.66	98.22	97.04	97.04





**Figure 91. Temperature and total dissolved gas time series near Columbia River Mile 192.3 during the Summer 1996 pool study (FMS-BC).**



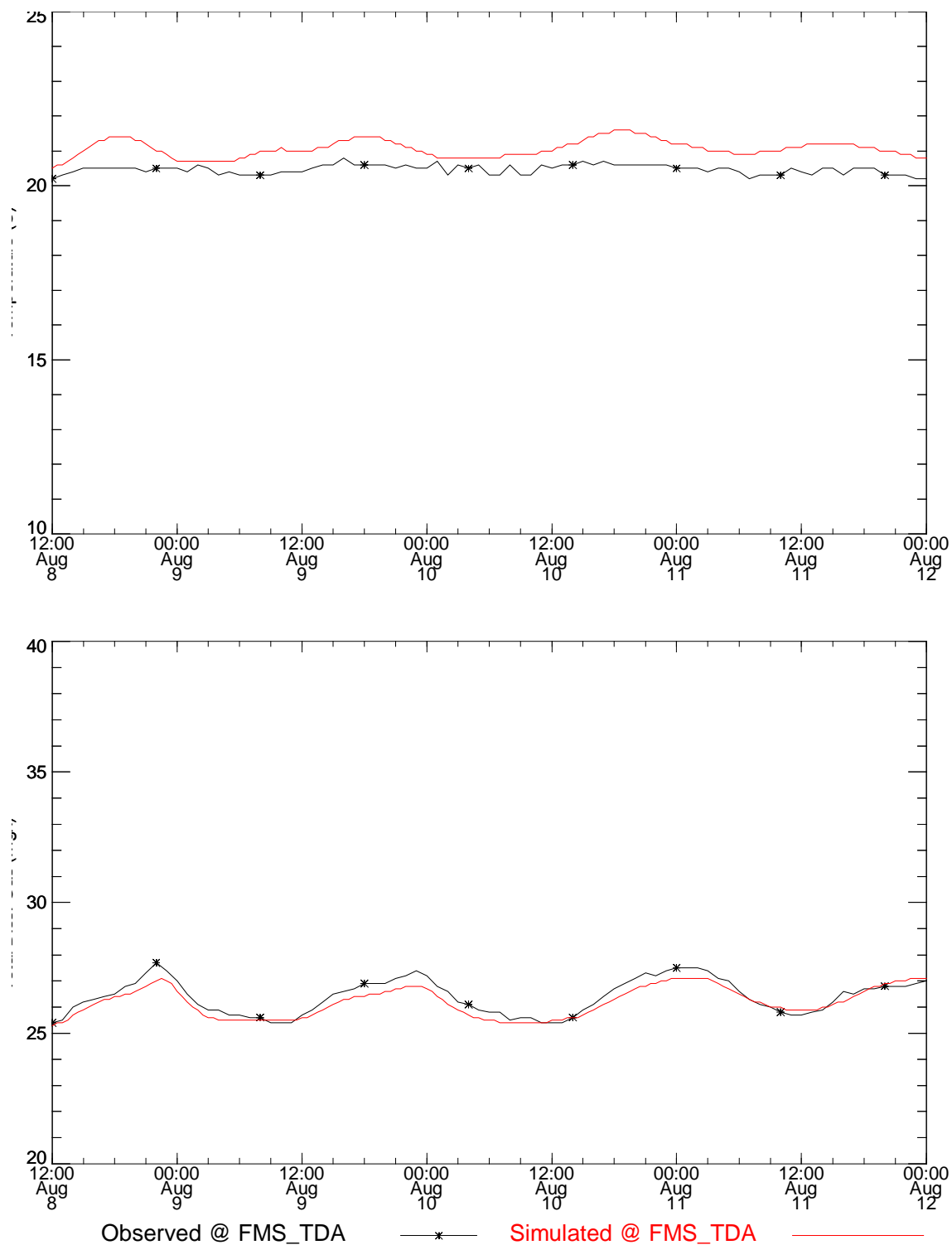
**Figure 92. Total dissolved gas time series comparisons near Columbia River Mile 192.3 during the Summer 1996 pool study (FMS-BC).**

**Table 45. Statistical summary of measurements and simulations at river mile 192.3 during the Summer 1996 pool study (FMS-BC).**

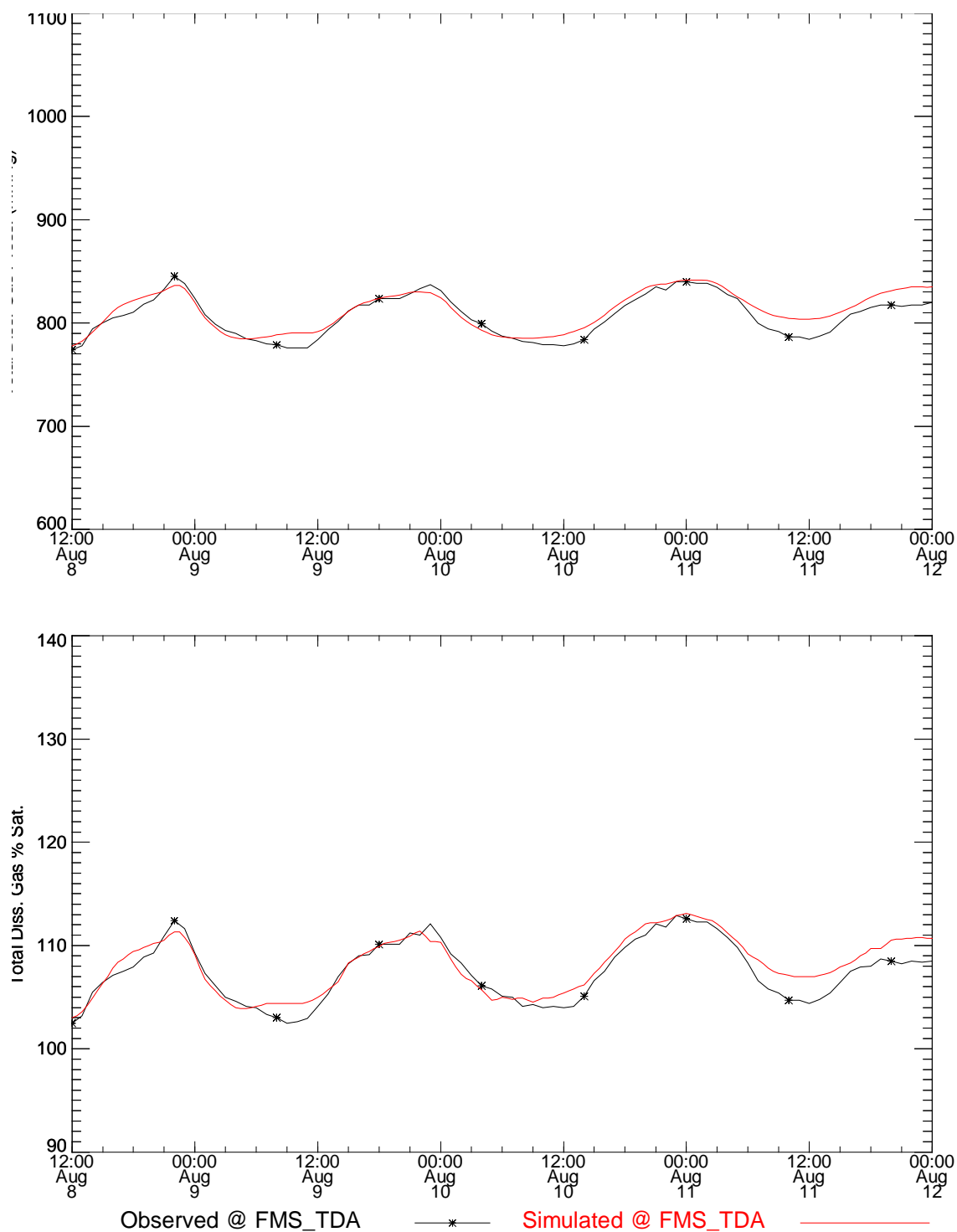
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA19234P	20.27	21.03	0.06	0.23	0.80
Concentration (mg/l)					
TDA19234P	26.81	26.55	0.89	0.76	0.35
Gas Pressure (mmHg)					
TDA19234P	815.58	821.95	26.38	23.99	9.29
% Saturation					
TDA19234P	108.70	109.51	3.75	3.43	1.23

**Table 46. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 192.3 during the Summer 1996 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA19234P	85.21	100	100	100



**Figure 93. Temperature and total dissolved gas time series at the TDA fixed monitor during the Summer 1996 pool study (FMS-BC).**



**Figure 94. Total dissolved gas time series comparisons at the TDA fixed monitor during the Summer 1996 pool study (FMS-BC).**

**Table 47. Statistical summary of measurements and simulations at the TDA fixed monitor during the Summer 1996 pool study (FMS-BC).**

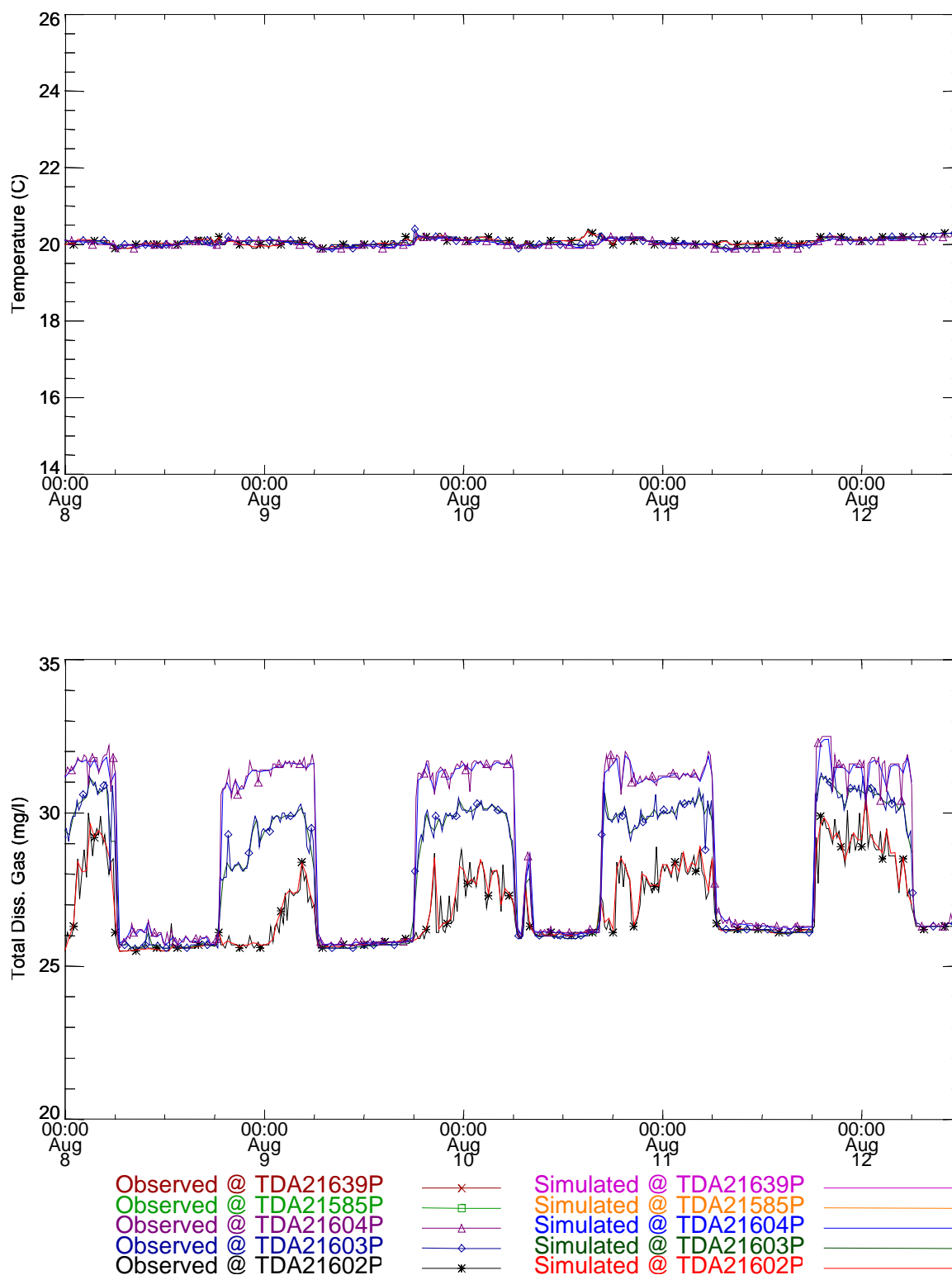
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_TDA	20.47	21.06	0.13	0.24	0.63
Concentration (mg/l)					
FMS_TDA	26.39	26.19	0.65	0.56	0.29
Gas Pressure (mmHg)					
FMS_TDA	806.31	811.45	19.83	18.53	8.70
% Saturation					
FMS_TDA	107.47	108.11	2.87	2.72	1.15

**Table 48. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the TDA fixed monitor during the Summer 1996 study (FMS-BC).**

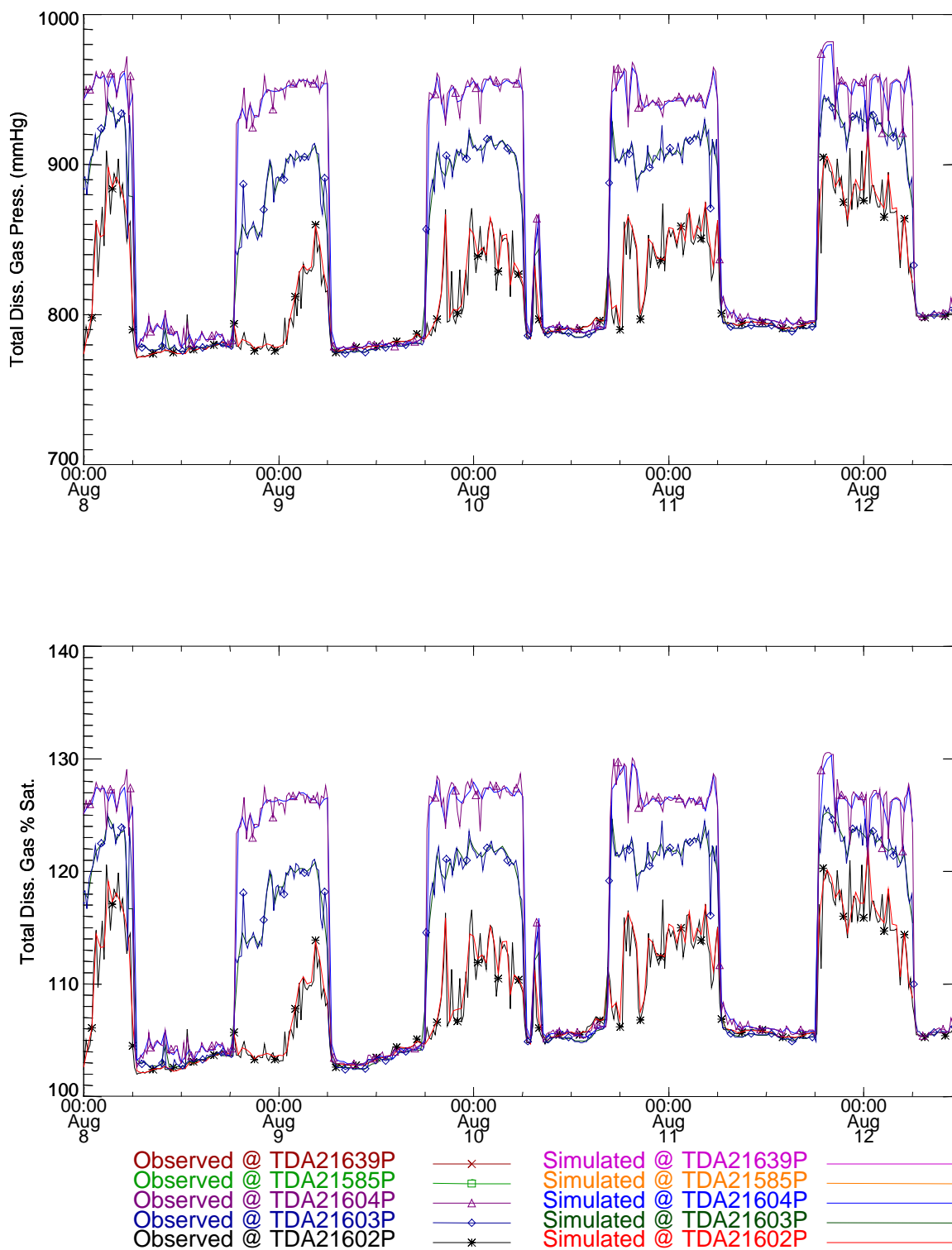
Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_TDA	100	100	100	100

**Boundary Conditions using Temporary Monitored Field Data**

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.



**Figure 95. Temperature and total dissolved gas time series near Columbia River Mile 216.0 during the Summer 1996 pool study (TM-BC).**



**Figure 96. Total dissolved gas time series comparisons near Columbia River Mile 216.0 during the Summer 1996 pool study (TM-BC).**

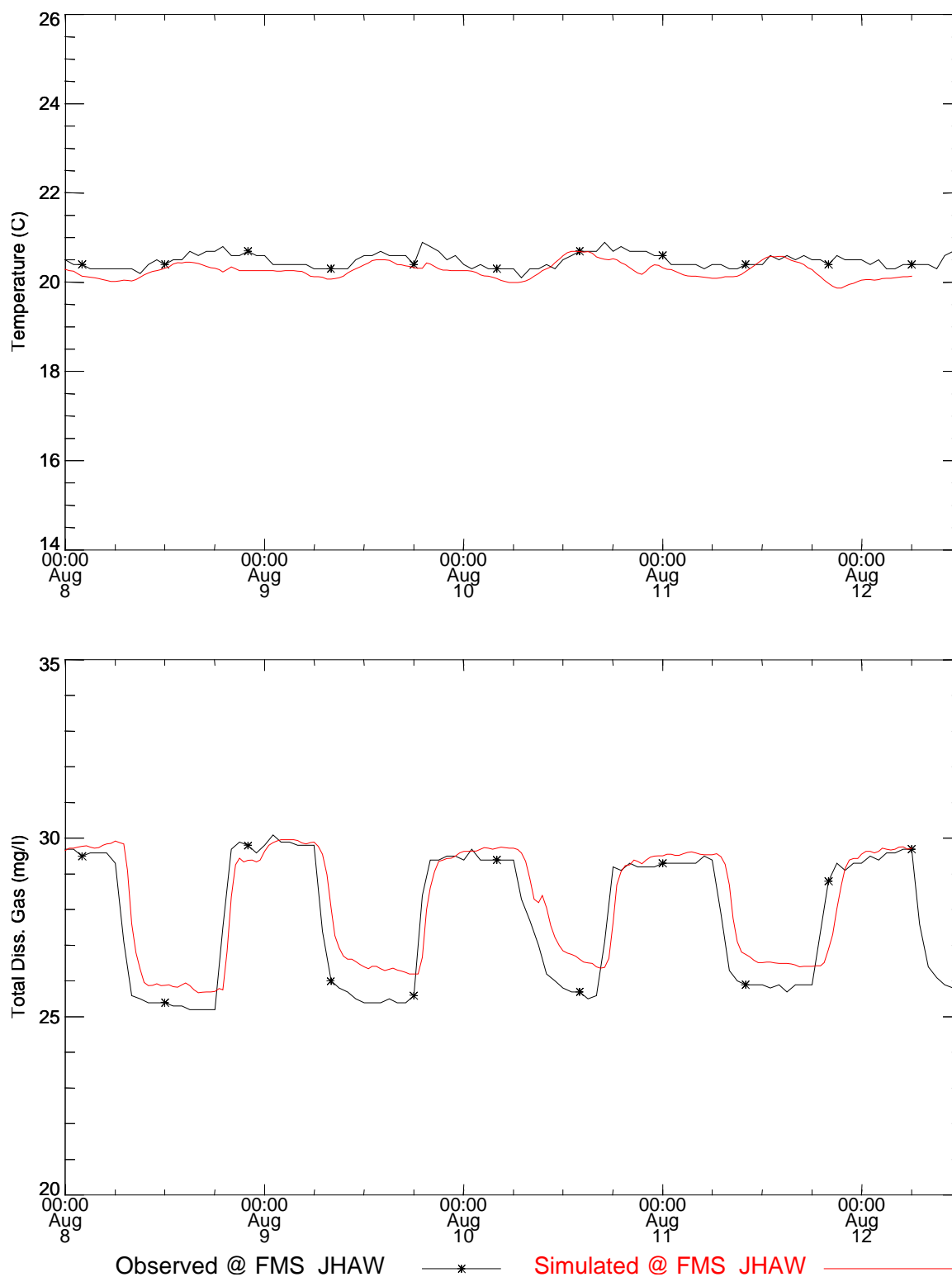


**Table 49. Statistical summary of measurements and simulations near river mile 216.0 during the Summer 1996 pool study (TM-BC).**

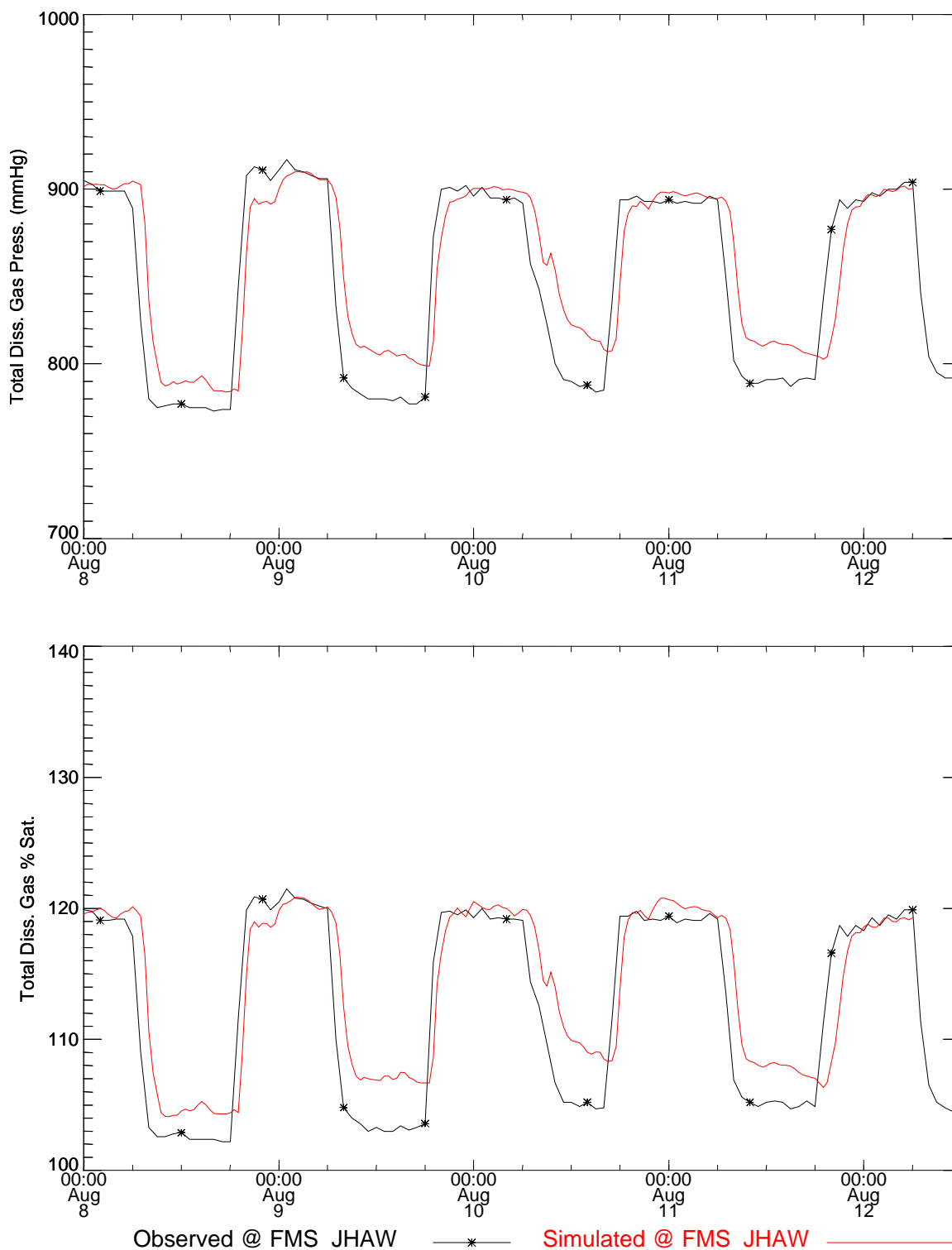
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA21602P	20.07	20.07	0.09	0.08	0.03
TDA21603P	20.06	20.05	0.09	0.08	0.03
TDA21604P	20.03	20.02	0.09	0.08	0.03
Concentration					
TDA21602P	26.85	26.87	1.26	1.28	0.09
TDA21603P	28.1	28.09	2.06	2.08	0.08
TDA21604P	28.99	28.96	2.68	2.66	0.13
Gas Pressure					
TDA21602P	813.83	815	37.95	38.48	2.83
TDA21603P	850.79	851.04	62.2	62.46	2.24
TDA21604P	876.73	876.29	80.58	80.07	3.67
% Saturation					
TDA21602P	108.34	108.5	5.1	5.18	0.45
TDA21603P	113.27	113.3	8.37	8.42	0.34
TDA21604P	116.71	116.66	10.81	10.76	0.53

**Table 50. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 216.0 during the Summer of 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA21602P	100	100	100	100
TDA21603P	100	100	100	100
TDA21604P	100	99.51	99.51	99.51



**Figure 97. Temperature and total dissolved gas time series at the JHAW fixed monitor during the Summer 1996 pool study (TM-BC).**



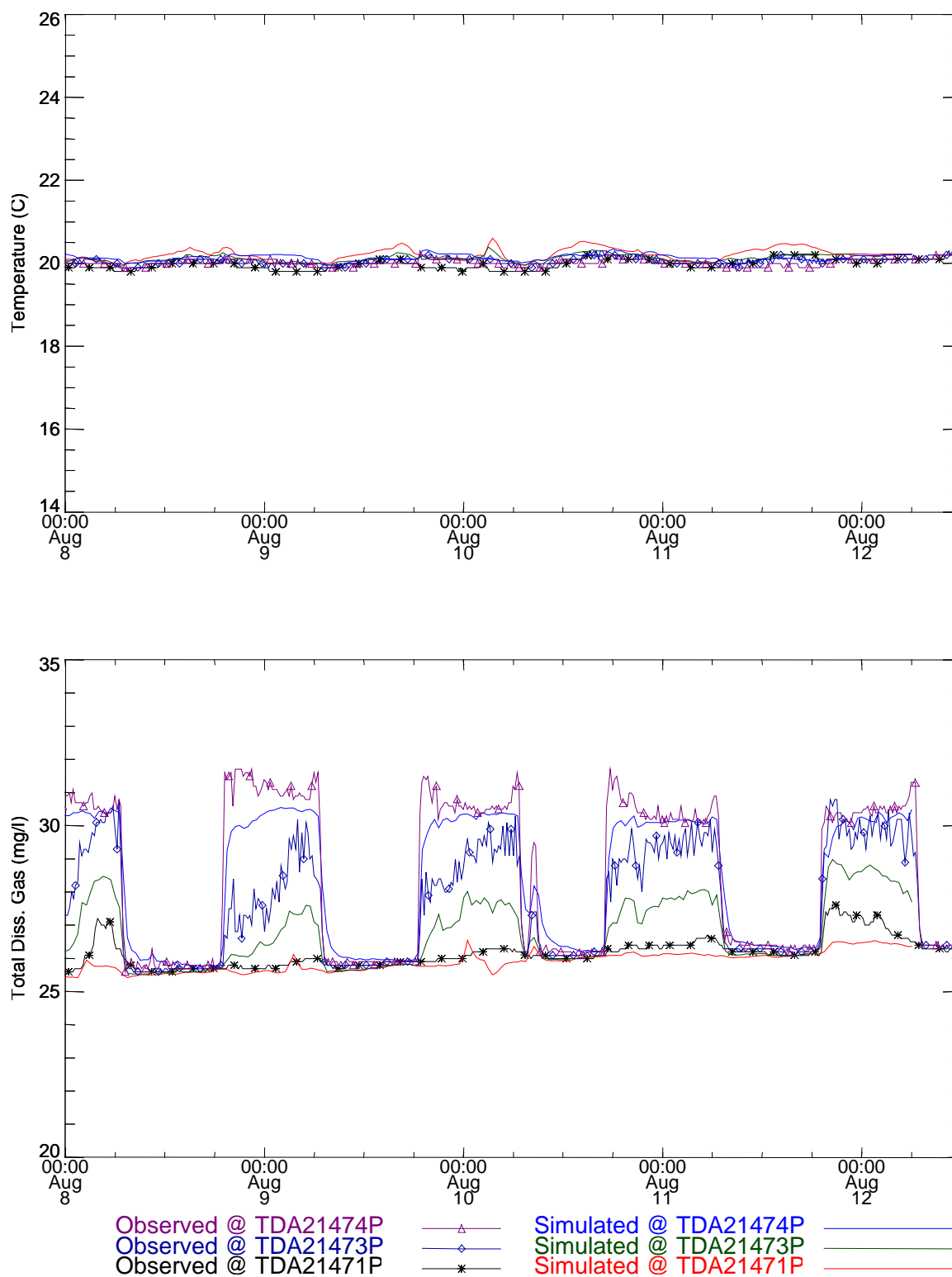
**Figure 98. Total dissolved gas time series comparisons at the JHAW fixed monitor during the Summer 1996 pool study (TM-BC).**

**Table 51. Statistical summary of measurements and simulations at the JHAW fixed monitor during the Summer 1996 pool study (TM-BC).**

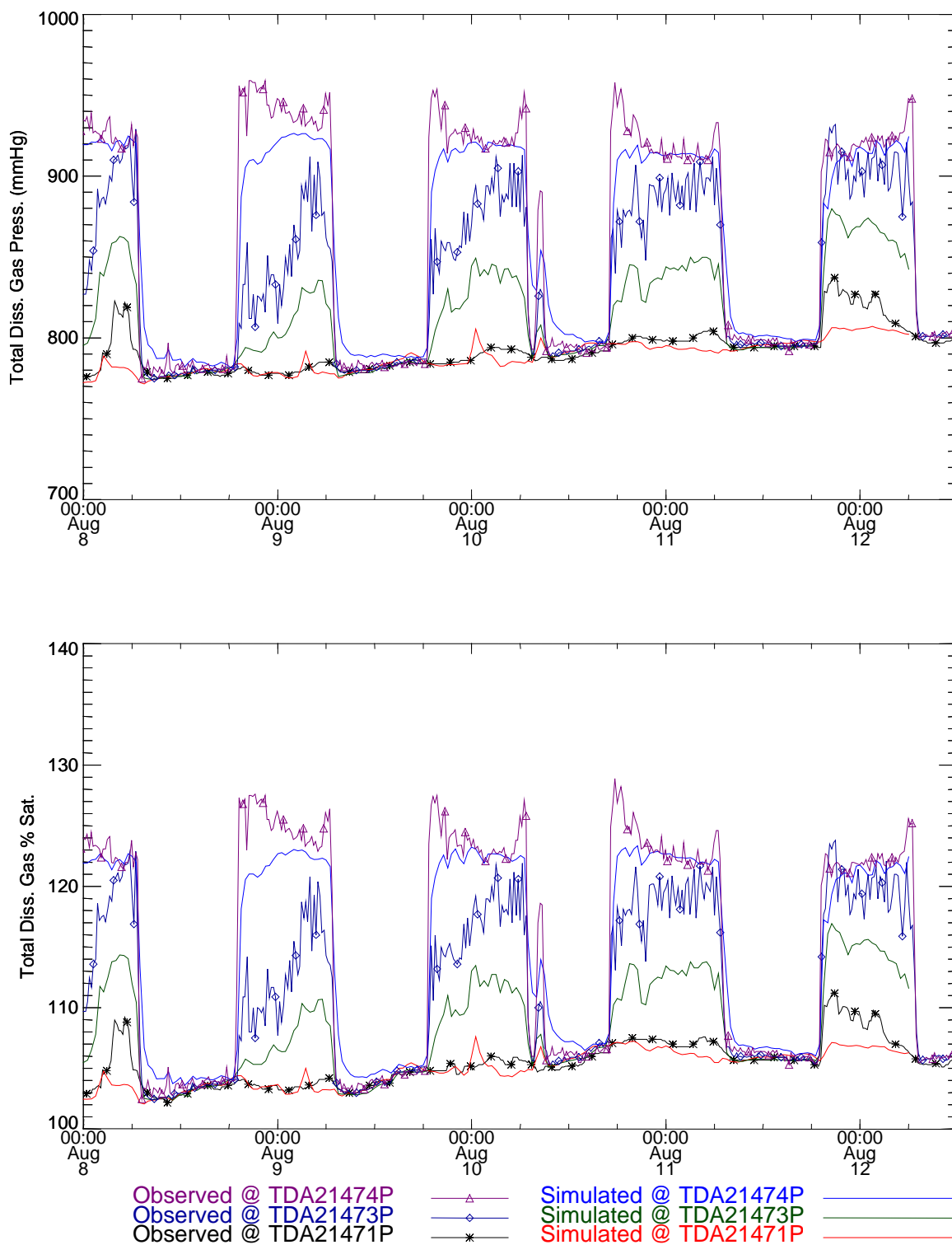
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_JHAW	20.48	20.26	0.16	0.18	0.27
Concentration					
FMS_JHAW	27.8	28.18	1.82	1.56	0.86
Gas Pressure					
FMS_JHAW	848.41	856.92	54.1	44.93	25.76
% Saturation					
FMS_JHAW	112.7	114.08	7.28	6.06	3.45

**Table 52. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the JHAW fixed monitor during the Summer 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_JHAW	100	78.54	87.32	86.34



**Figure 99. Temperature and total dissolved gas time series near Columbia River Mile 214.7 during the Summer 1996 pool study (TM-BC).**



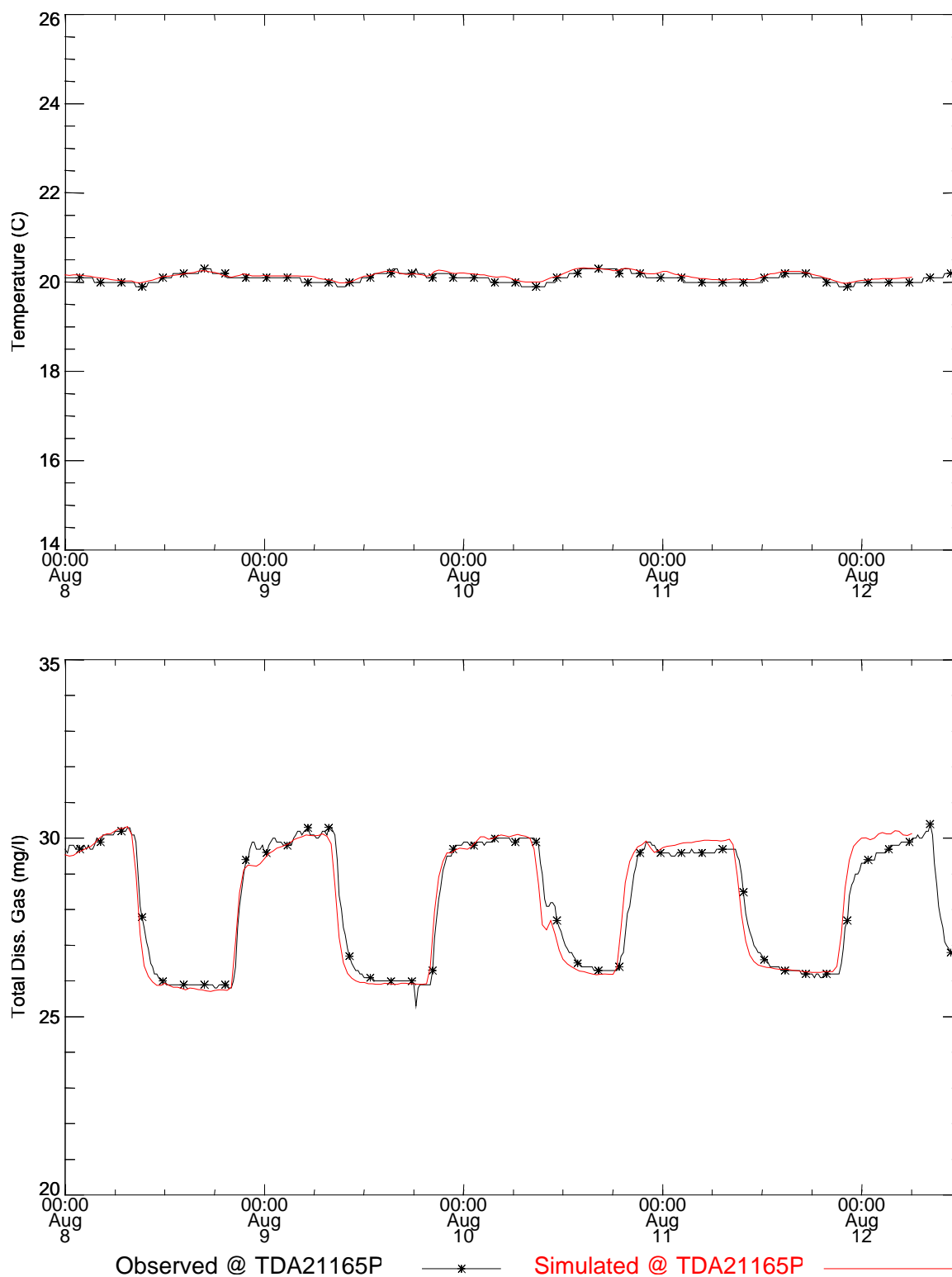
**Figure 100. Total dissolved gas time series comparisons near Columbia River Mile 214.7 during the Summer 1996 pool study (TM-BC).**

**Table 53. Statistical summary of measurements and simulations near river mile 214.7 during the Summer 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA21471P	15.03	15.03	0.24	0.24	0.03
TDA21472P	14.97	14.97	0.23	0.23	0.03
TDA21473P	15.01	14.97	0.23	0.23	0.05
TDA21474P	15.06	15.05	0.24	0.23	0.03
TDA21475P	14.83	14.83	0.23	0.23	0.03
Concentration					
TDA21471P	32.4	32.39	0.49	0.49	0.03
TDA21472P	33.72	33.58	0.86	0.81	0.16
TDA21473P	33.08	33.7	1.52	0.85	1.05
TDA21474P	36.38	36.37	1.59	1.59	0.05
TDA21475P	36.98	36.97	2.21	2.21	0.04
Gas Pressure					
TDA21471P	887.67	887.68	11.79	11.78	0.1
TDA21472P	921.99	918.71	20.03	18.88	3.58
TDA21473P	905.42	922	38.34	20.01	28.24
TDA21474P	995.5	995.62	39.92	39.92	1.29
TDA21475P	1007.04	1007.11	56.42	56.39	0.66
% Saturation					
TDA21471P	116.94	116.94	1.84	1.85	0.11
TDA21472P	121.46	121.03	2.74	2.61	0.48
TDA21473P	119.28	121.46	5.15	2.74	3.73
TDA21474P	131.13	131.15	5.15	5.15	0.21
TDA21475P	132.65	132.66	7.35	7.34	0.15

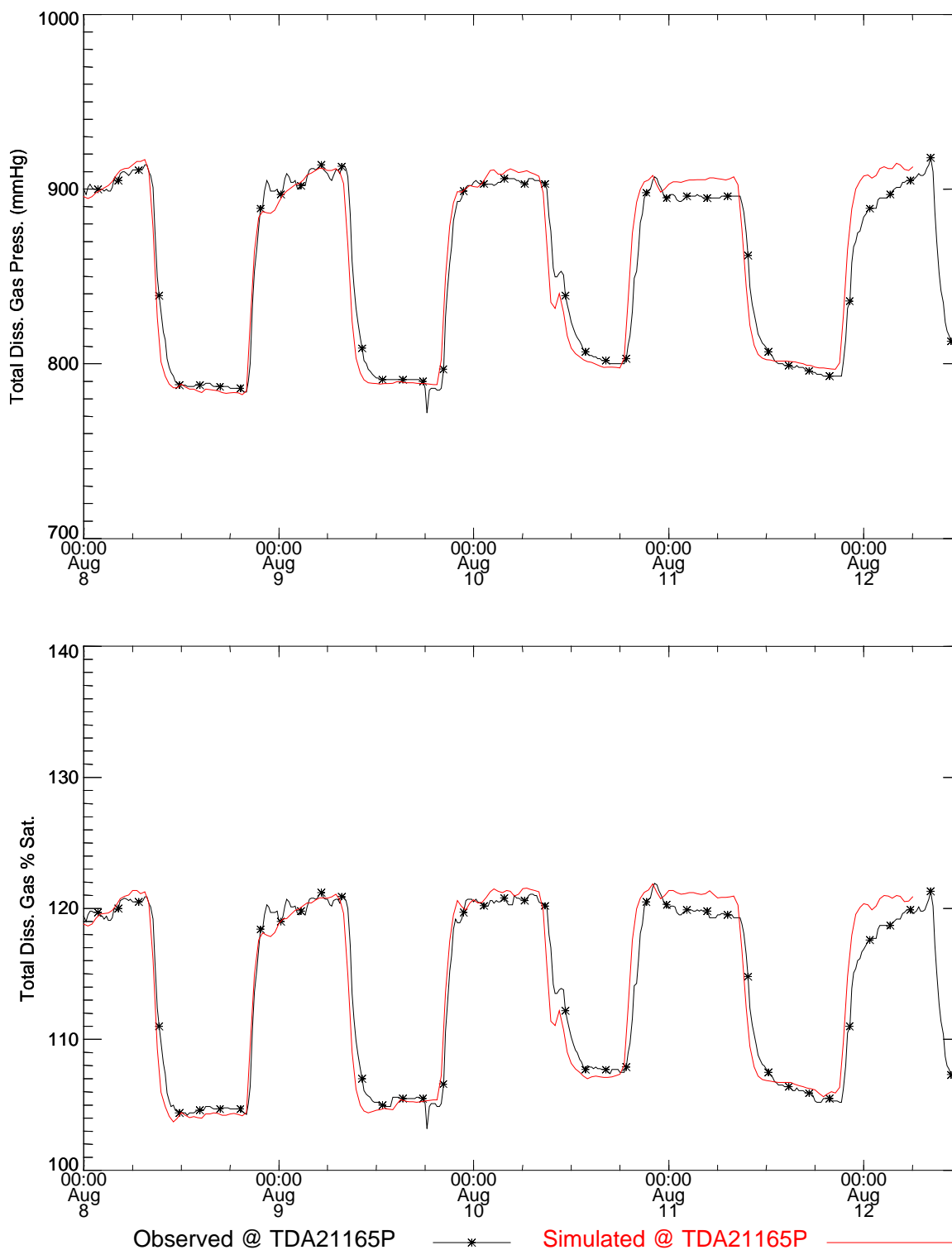
**Table 54. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 214.7 during the Summer 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA21471P	100	100	100	100
TDA21472P	100	100	100	100
TDA21473P	100	65.33	77.08	77.08
TDA21474P	100	100	100	100
TDA21475P	100	100	100	100



**Figure 101. Temperature and total dissolved gas time series near Columbia River Mile 211.6 during the Summer 1996 pool study (TM-BC).**





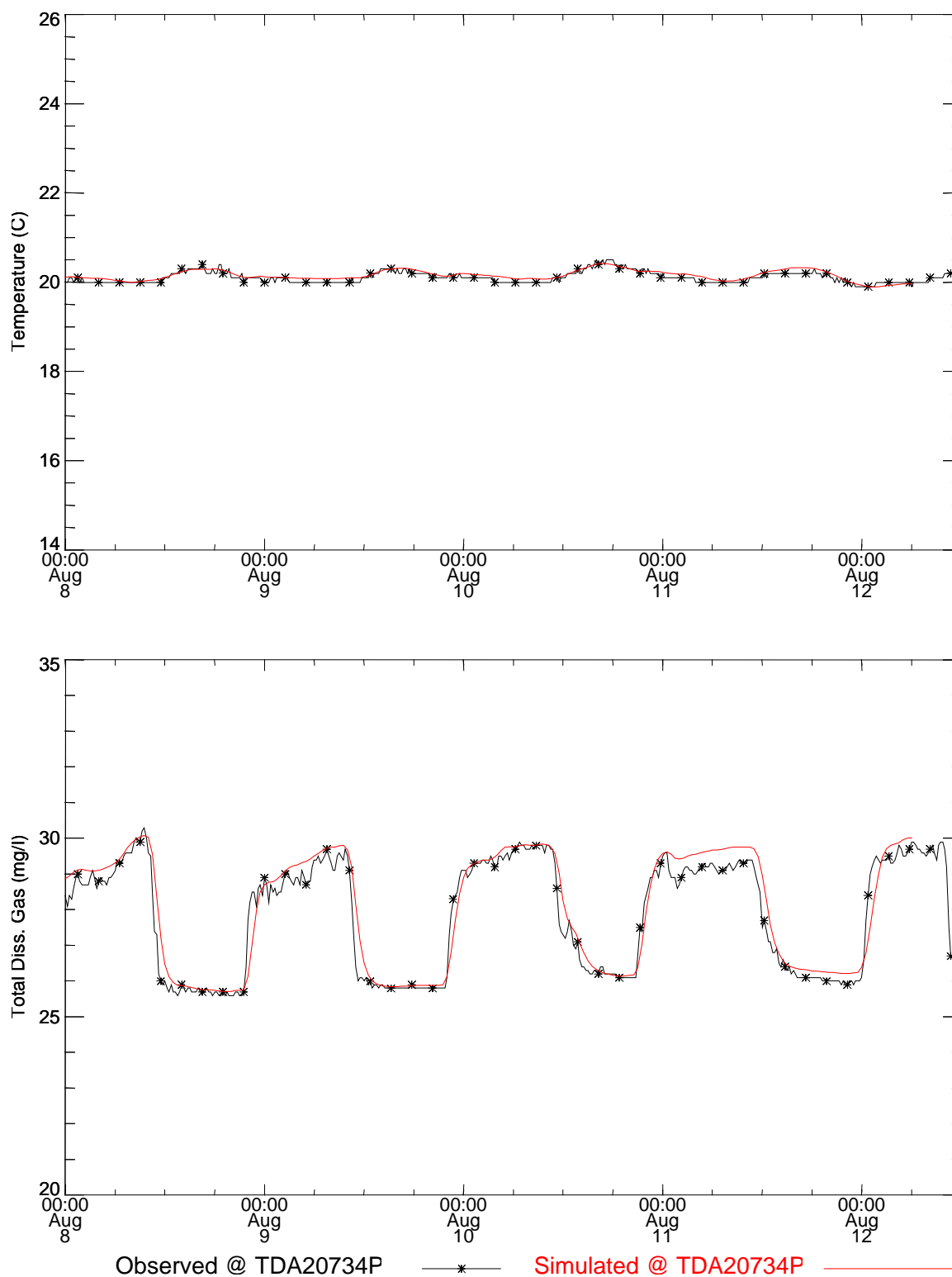
**Figure 102. Total dissolved gas time series comparisons near Columbia River Mile 211.6 during the Summer 1996 pool study (TM-BC).**

**Table 55. Statistical summary of measurements and simulations near river mile 211.6 during the Summer 1996 pool study (TM-BC).**

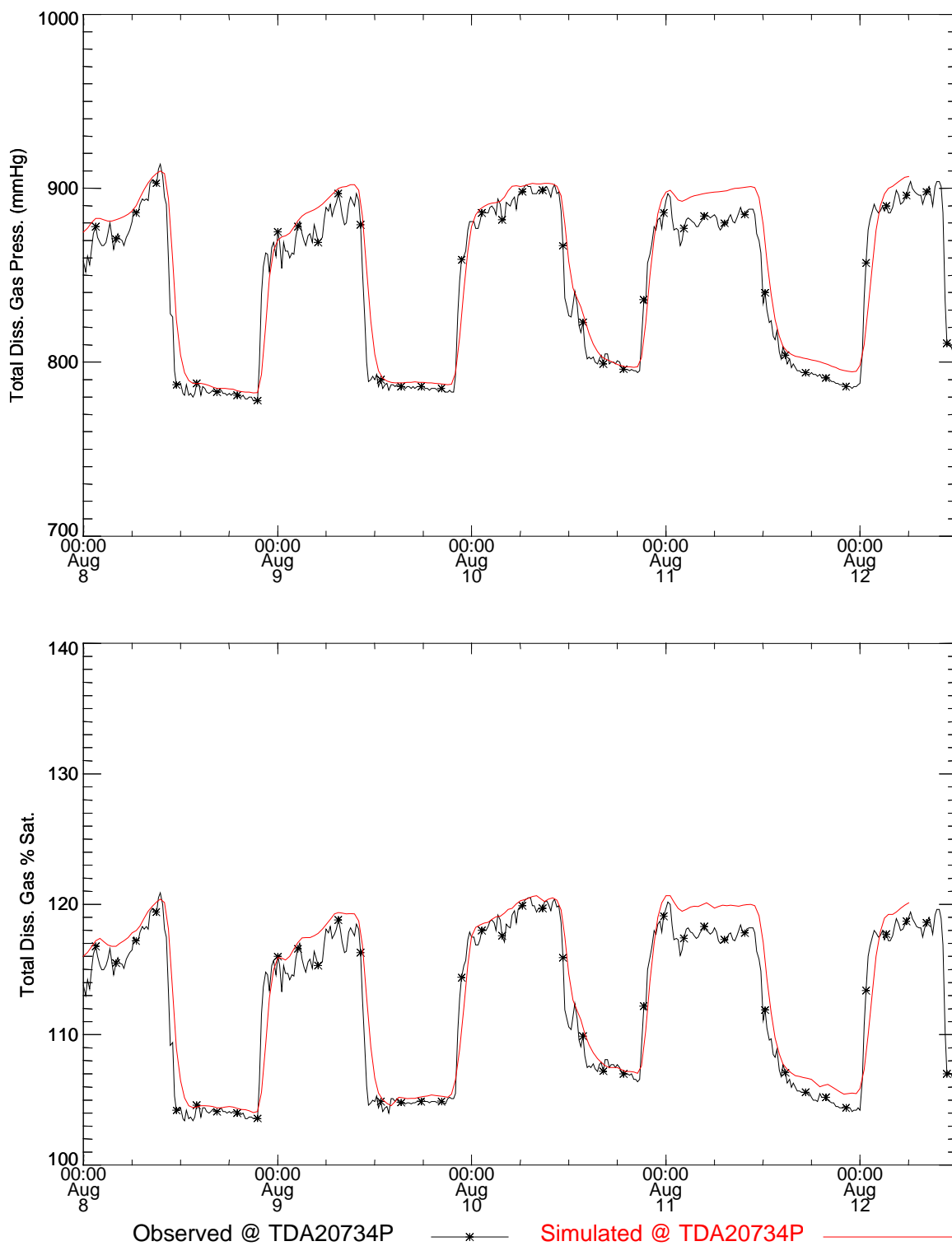
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA21165P	20.09	20.14	0.11	0.08	0.07
Concentration					
TDA21165P	28.22	28.2	1.71	1.8	0.42
Gas Pressure					
TDA21165P	854.65	855.68	50.09	53.04	12.44
% Saturation					
TDA21165P	113.77	113.91	6.63	7.09	1.69

**Table 56. Percentages of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 211.6 during the Summer 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA21165P	100	95.61	98.05	98.05



**Figure 103. Temperature and total dissolved gas time series near Columbia River Mile 207.3 during the Summer 1996 pool study (TM-BC).**



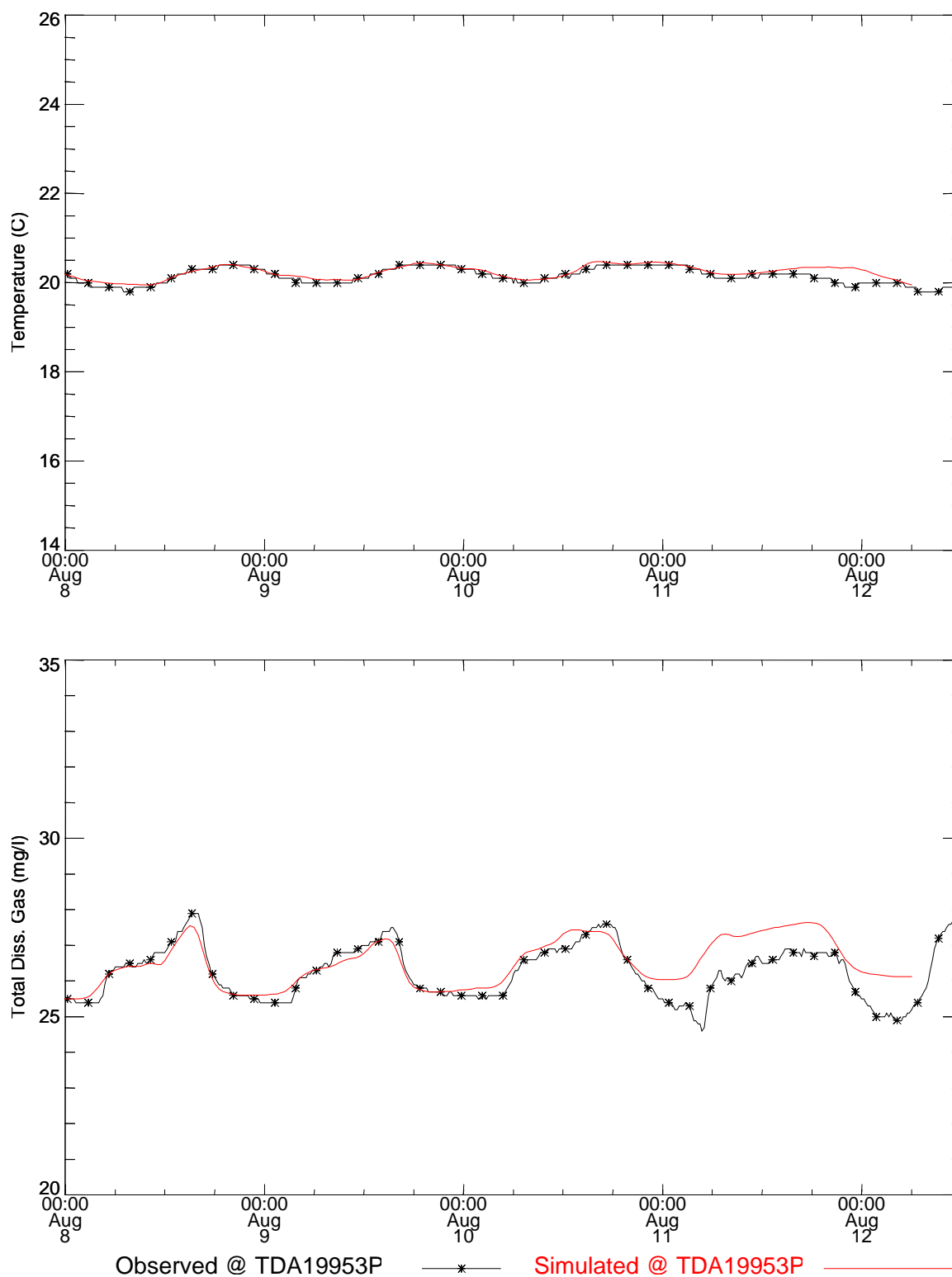
**Figure 104. Total dissolved gas time series comparisons near Columbia River Mile 207.3 during the Summer 1996 pool study (TM-BC).**

**Table 57. Statistical summary of measurements and simulations near river mile 207.3 during the Summer 1996 pool study (TM-BC).**

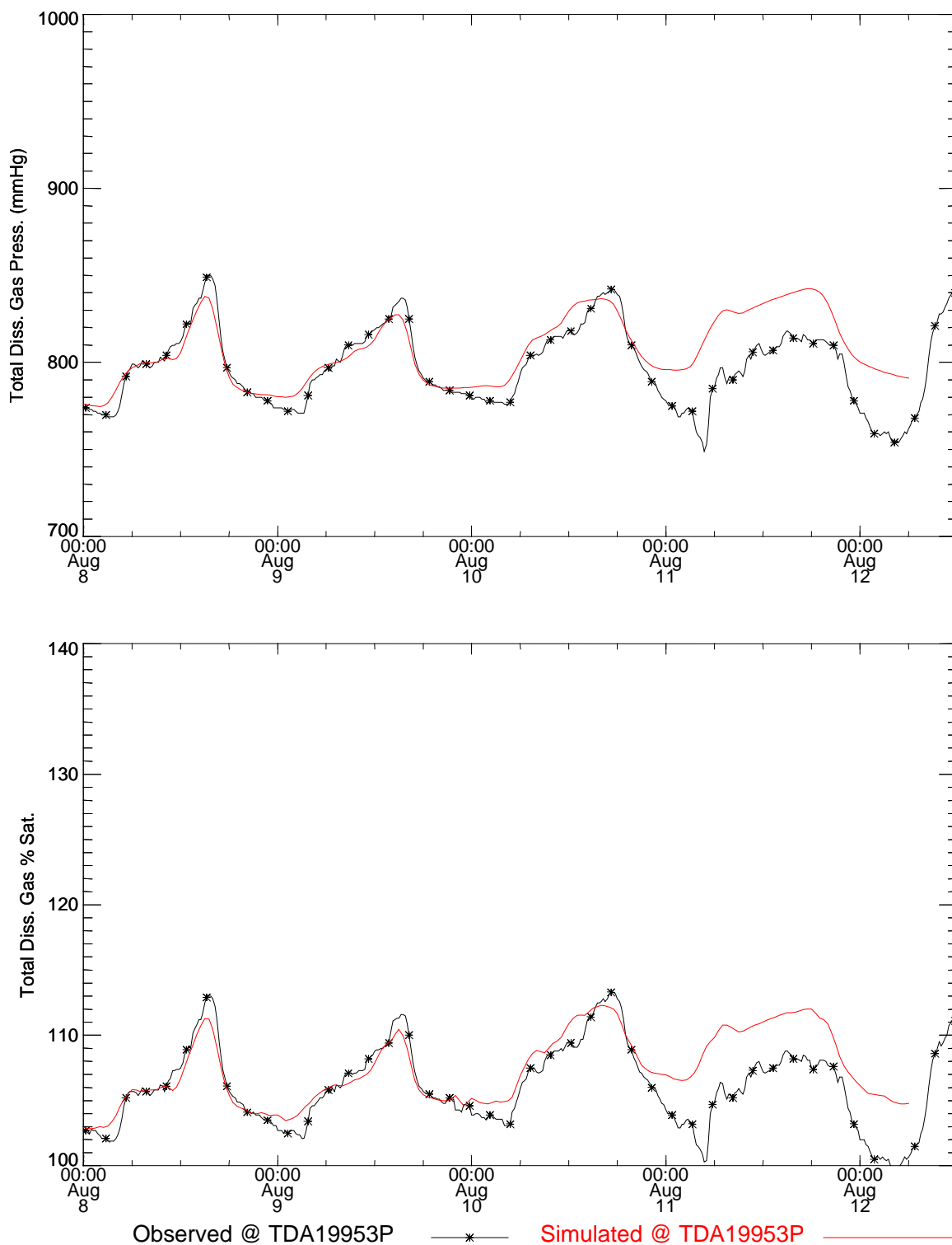
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA20734P	20.11	20.15	0.13	0.11	0.07
Concentration					
TDA20734P	27.8	28	1.57	1.63	0.46
Gas Pressure					
TDA20734P	842.58	849.94	45.4	47.32	14.35
% Saturation					
TDA20734P	112.16	113.14	5.97	6.23	1.92

**Table 58. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 207.3 during the Summer 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA20734P	100	94.15	97.07	97.07



**Figure 105. Temperature and total dissolved gas time series near Columbia River Mile 195.5 during the Summer 1996 pool study (TM-BC).**



**Figure 106. Total dissolved gas time series comparisons near Columbia River Mile 195.5 during the Summer 1996 pool study (TM-BC).**

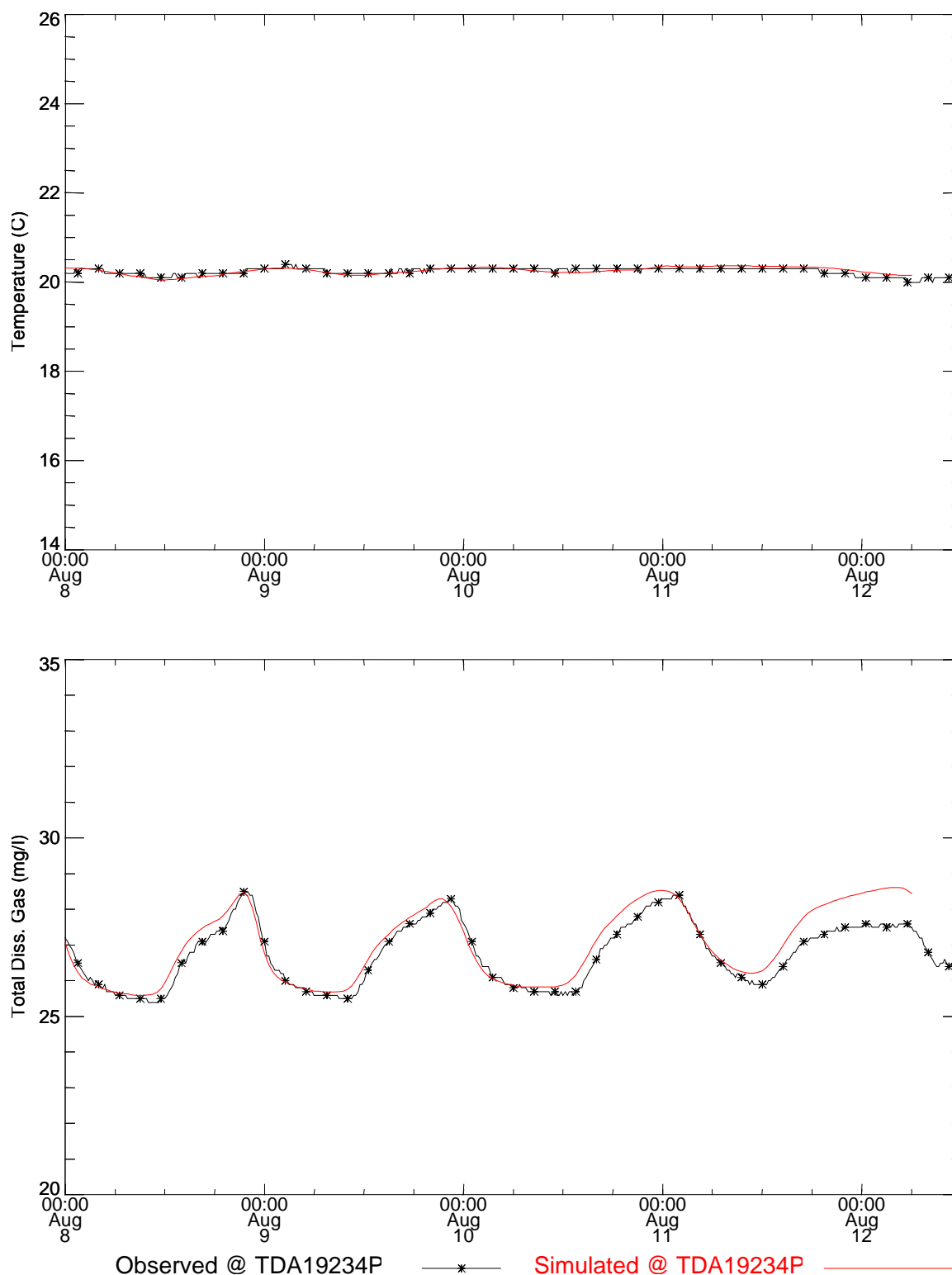
**Table 59. Statistical summary of measurements and simulations at river mile 195.5 during the Summer 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA19953P	20.17	20.23	0.17	0.15	0.11
Concentration					
TDA19953P	26.22	26.51	0.74	0.65	0.56
Gas Pressure					
TDA19953P	796.42	806.67	22.16	19.5	18.05
% Saturation					
TDA19953P	106.03	107.39	3.08	2.72	2.43

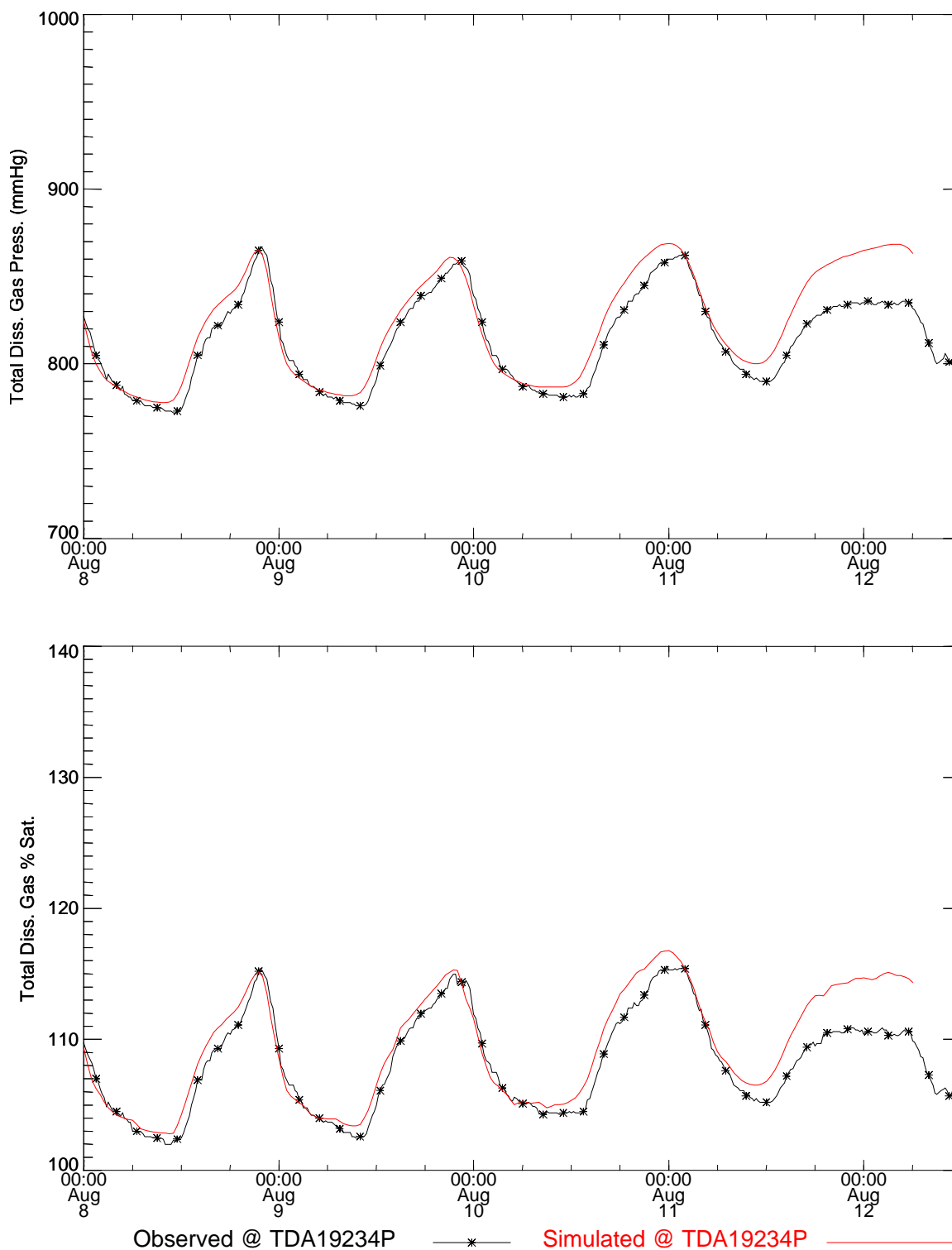
**Table 60. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 195.5 during the Summer 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA19953P	100	89.76	97.07	96.59





**Figure 107. Temperature and total dissolved gas time series near Columbia River Mile 192.3 during the Summer 1996 pool study (TM-BC).**



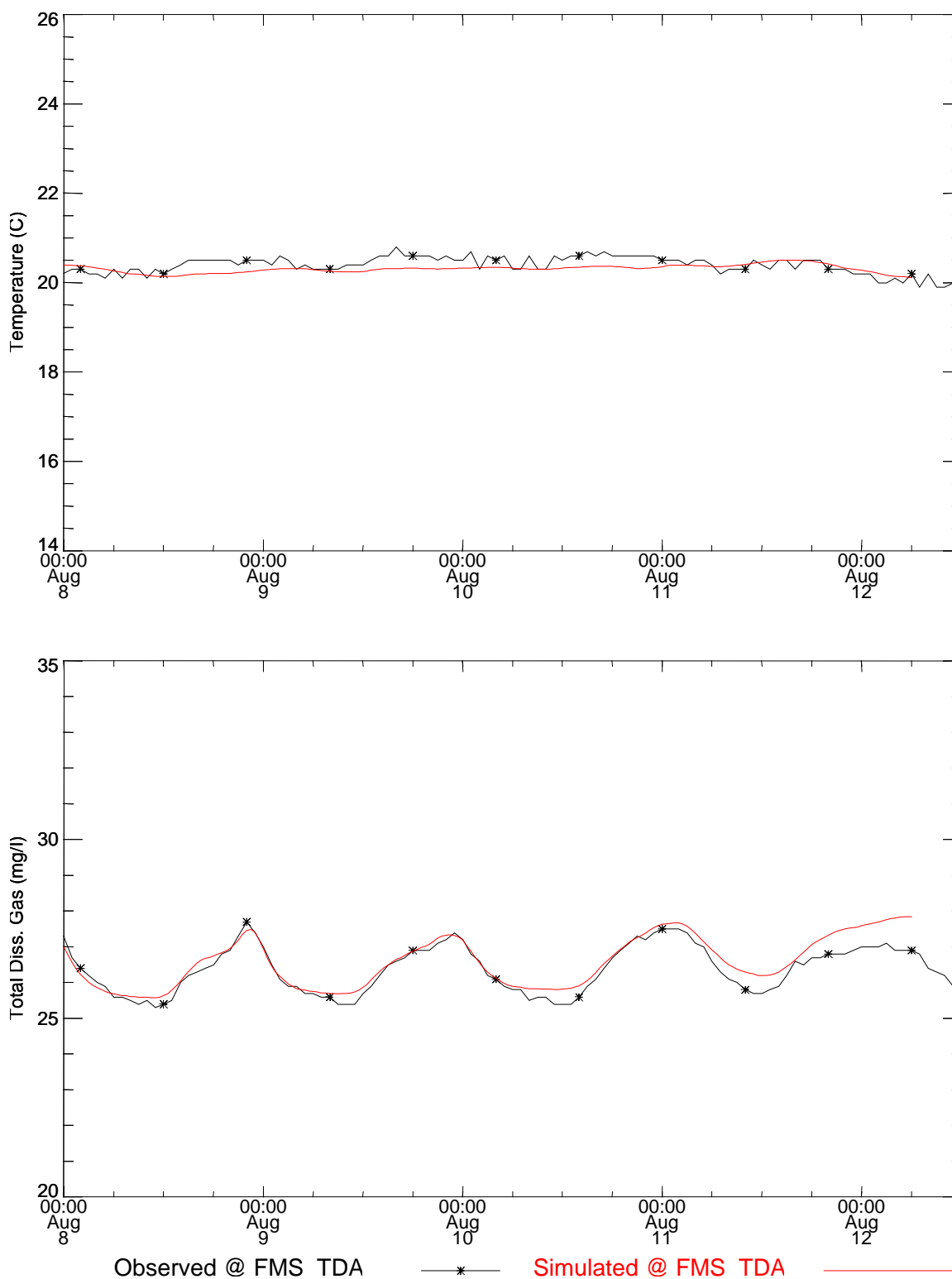
**Figure 108. Total dissolved gas time series comparisons near Columbia River Mile 192.3 during the Summer 1996 pool study (TM-BC).**

**Table 61. Statistical summary of measurements and simulations at river mile 192.3 during the Summer 1996 pool study (TM-BC).**

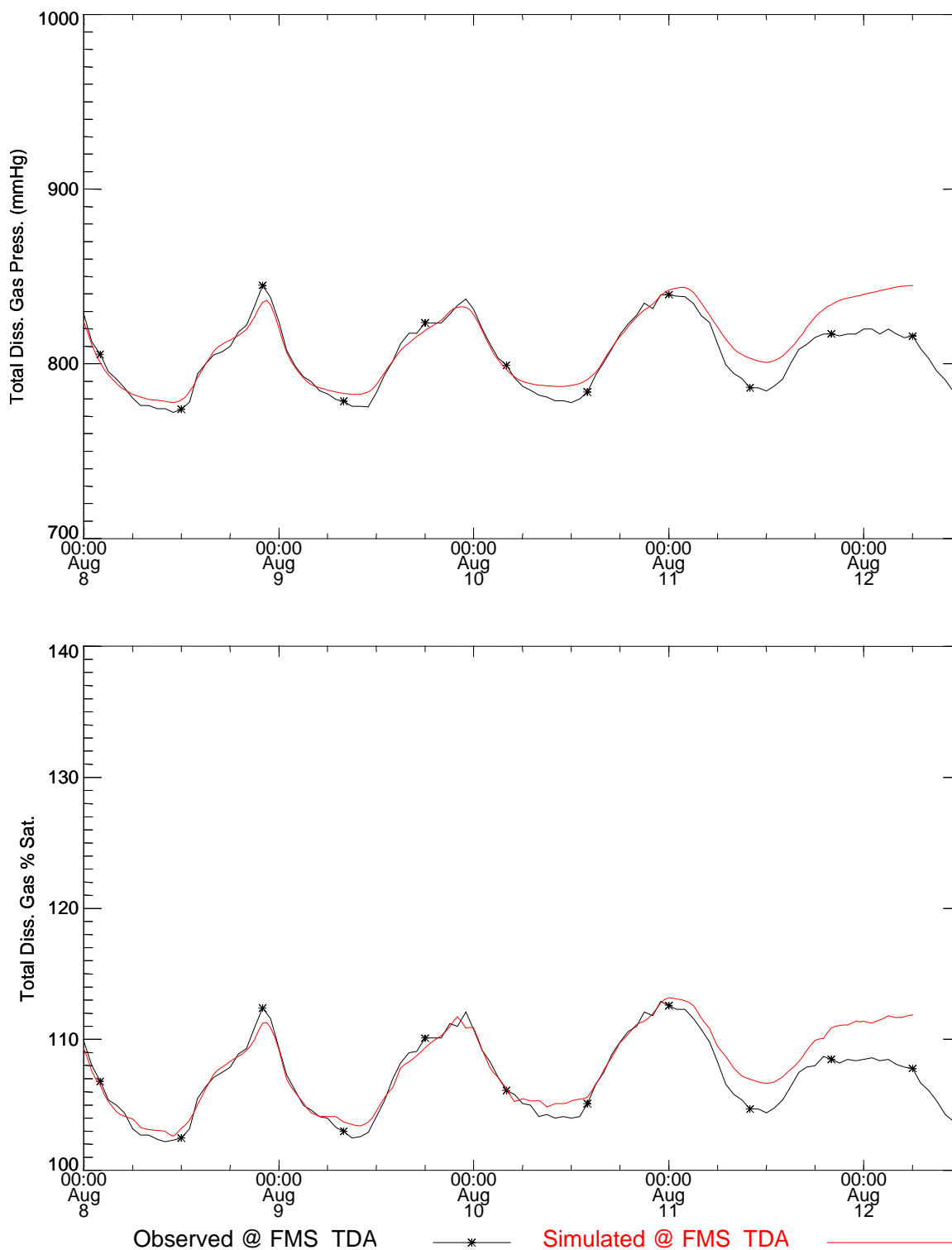
<b>Station</b>	<b>Measured Ave.</b>	<b>Simulated Ave.</b>	<b>Measured Std.Dev</b>	<b>Simulated Std.Dev.</b>	<b>RMS Error</b>
Temperature TDA19234P	20.25	20.26	0.07	0.08	0.06
Concentration TDA19234P	26.74	27.01	0.91	1.03	0.43
Gas Pressure TDA19234P	813.35	822.09	26.72	30.71	13.63
% Saturation TDA19234P	108.28	109.45	3.8	4.29	1.82

**Table 62. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 192.3 during the Summer 1996 study (TM-BC).**

<b>Station</b>	<b>1.00 C</b>	<b>1.00 mg/l</b>	<b>38.00 mmHg</b>	<b>5.00% Sat.</b>
TDA19234P	100	97.07	100	100



**Figure 109. Temperature and total dissolved gas time series at the TDA fixed monitor during the Summer 1996 pool study (TM-BC).**



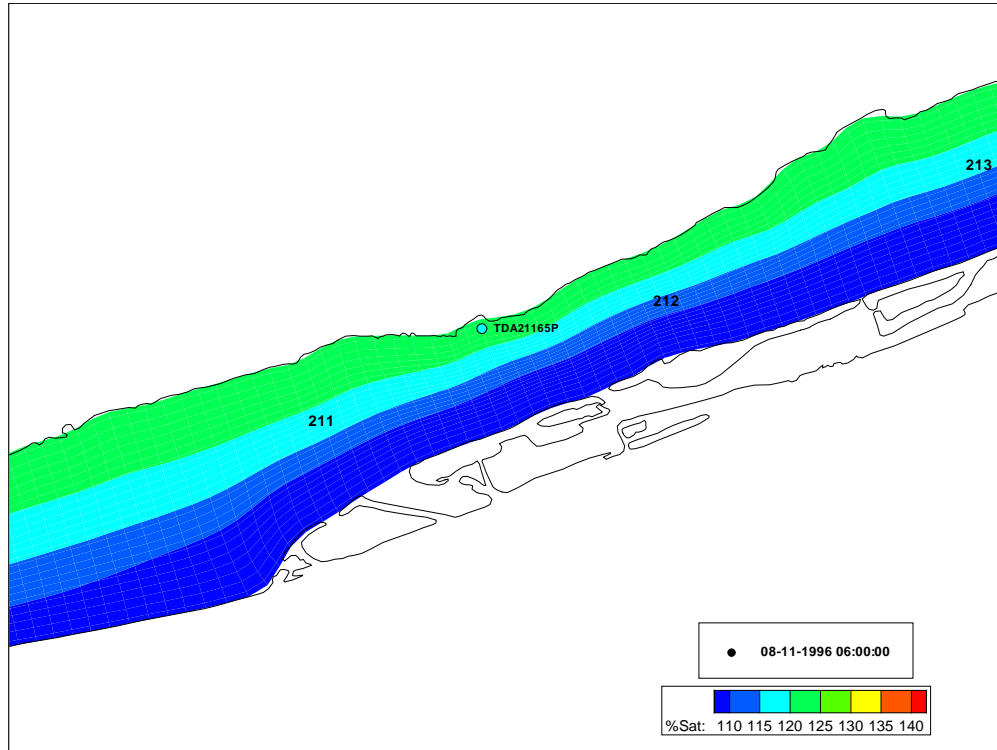
**Figure 110. Total dissolved gas time series comparisons at the TDA fixed monitor during the Summer 1996 pool study (TM-BC).**

**Table 63. Statistical summary of measurements and simulations at the TDA fixed monitor during the Summer 1996 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_TDA	20.42	20.31	0.16	0.09	0.19
Concentration					
FMS_TDA	26.37	26.58	0.65	0.69	0.32
Gas Pressure					
FMS_TDA	804.87	809.99	19.96	20.61	9.66
% Saturation					
FMS_TDA	107.16	107.83	2.9	2.95	1.31

**Table 64. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the TDA fixed monitor during the Summer 1996 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_TDA	100	100	100	100

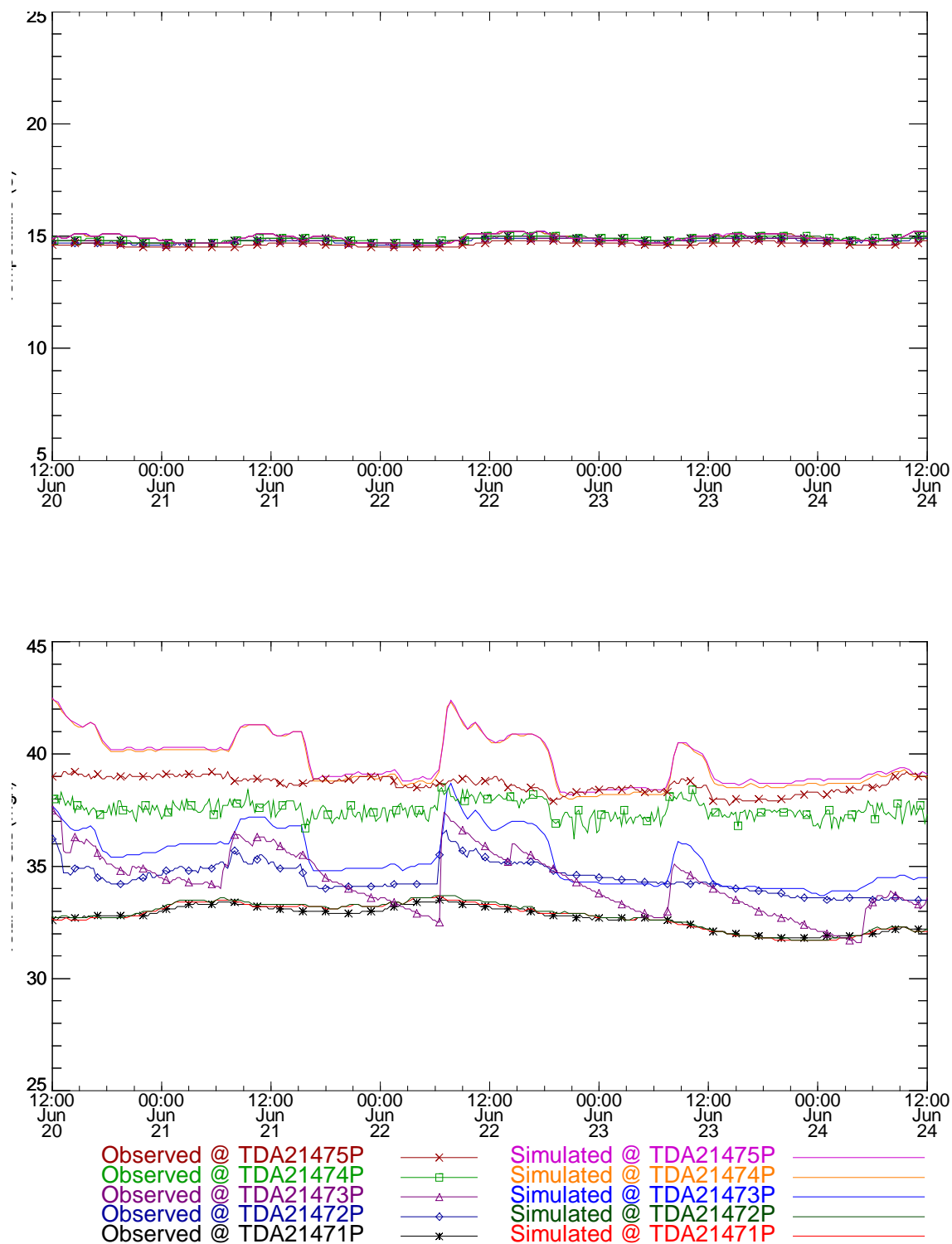


**Figure 111. Spatial distribution of dissolved gas near Columbia river mile 212 during the Summer 1996 study period.**

#### ***1.4.3 1997 Summer Simulation***

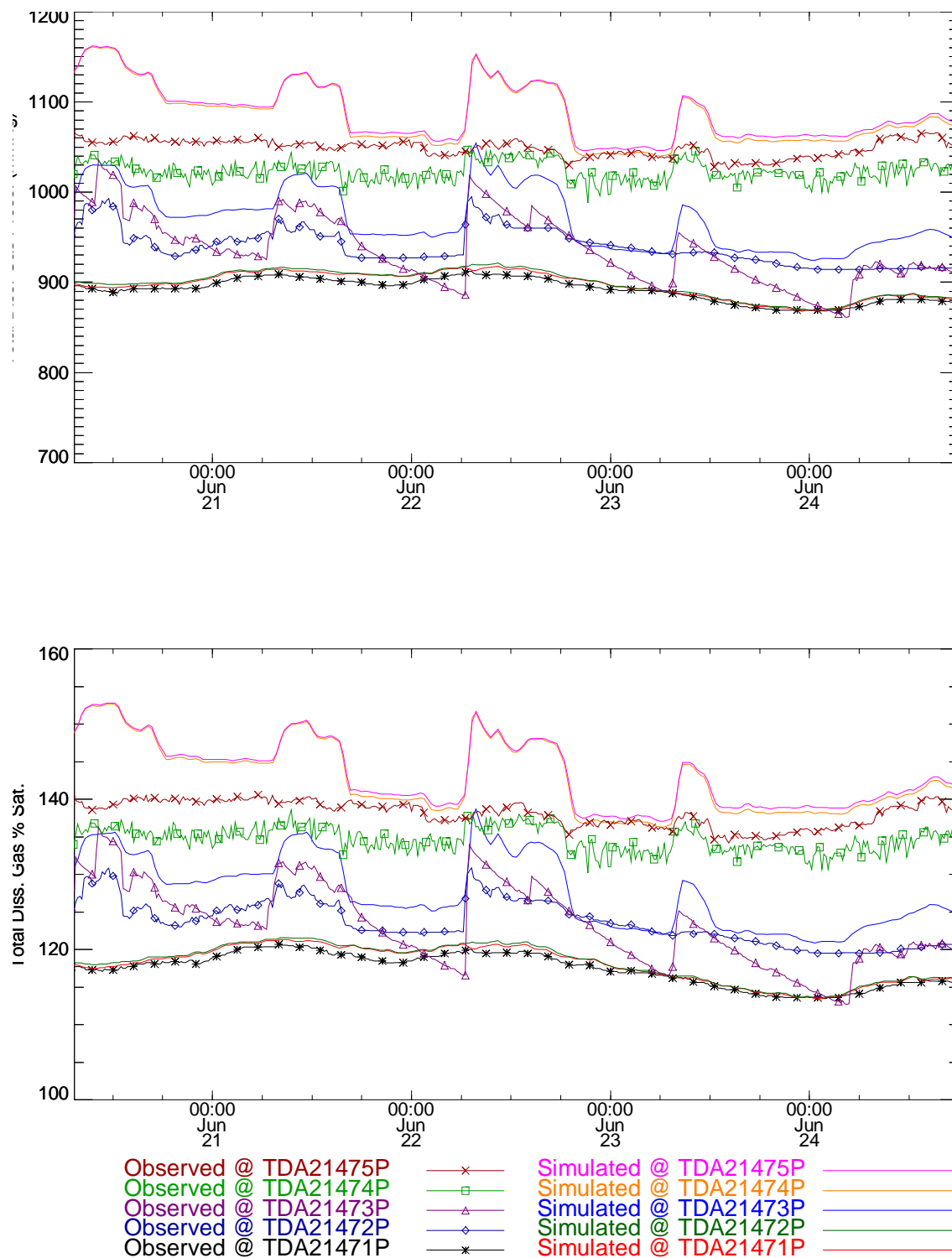
##### **Boundary Conditions using John Day Sourcing Function and Forebay FMS Data**

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.



**Figure 112. Temperature and total dissolved gas time series near Columbia River Mile 214.7 during the Summer 1997 pool study (FMS-BC).**





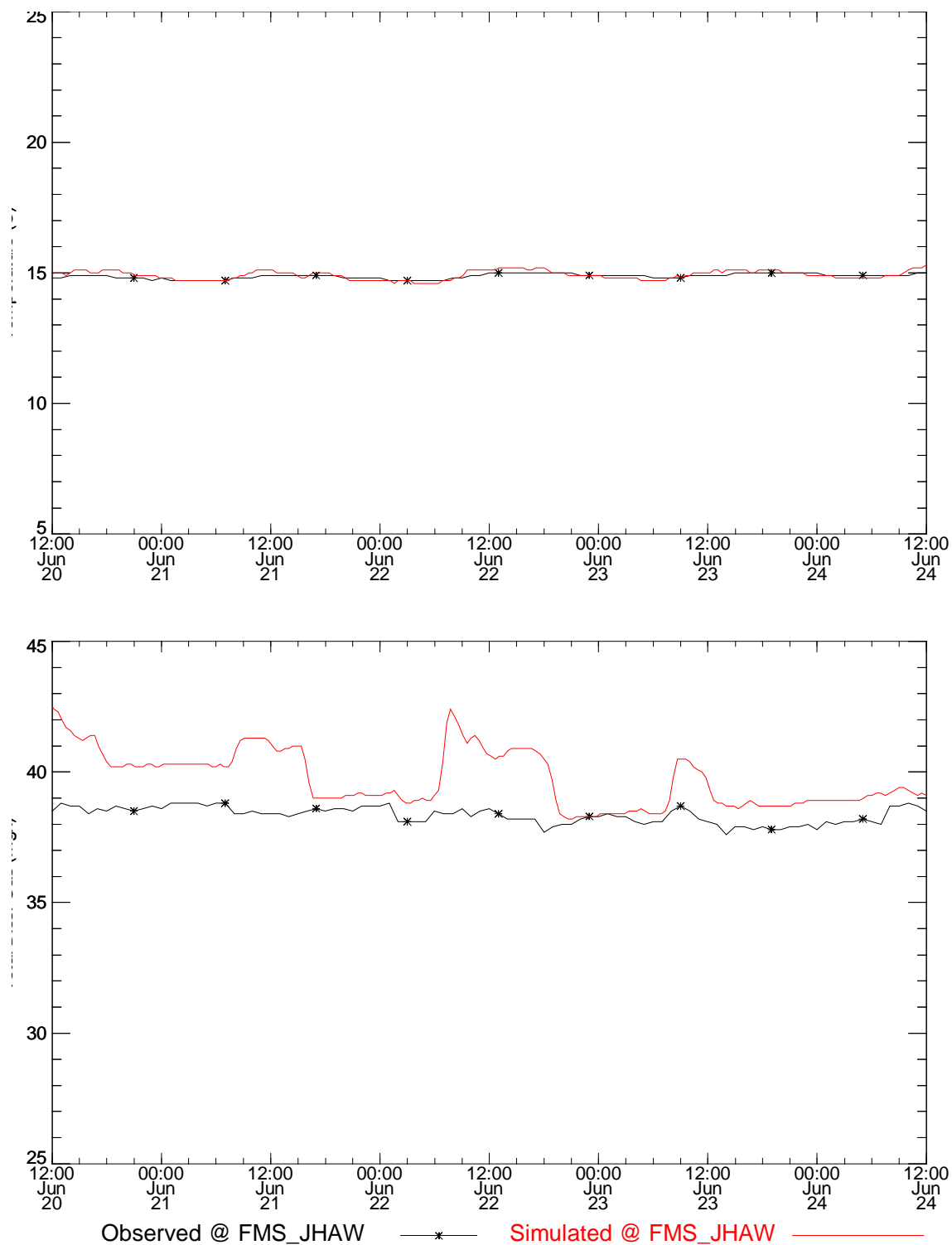
**Figure 113. Total dissolved gas time series comparisons near Columbia River Mile 214.7 during the Summer 1997 pool study (FMS-BC).**

**Table 65. Statistical summary of measurements and simulations at river mile 214.7 during the Summer 1997 pool study (FMS-BC).**

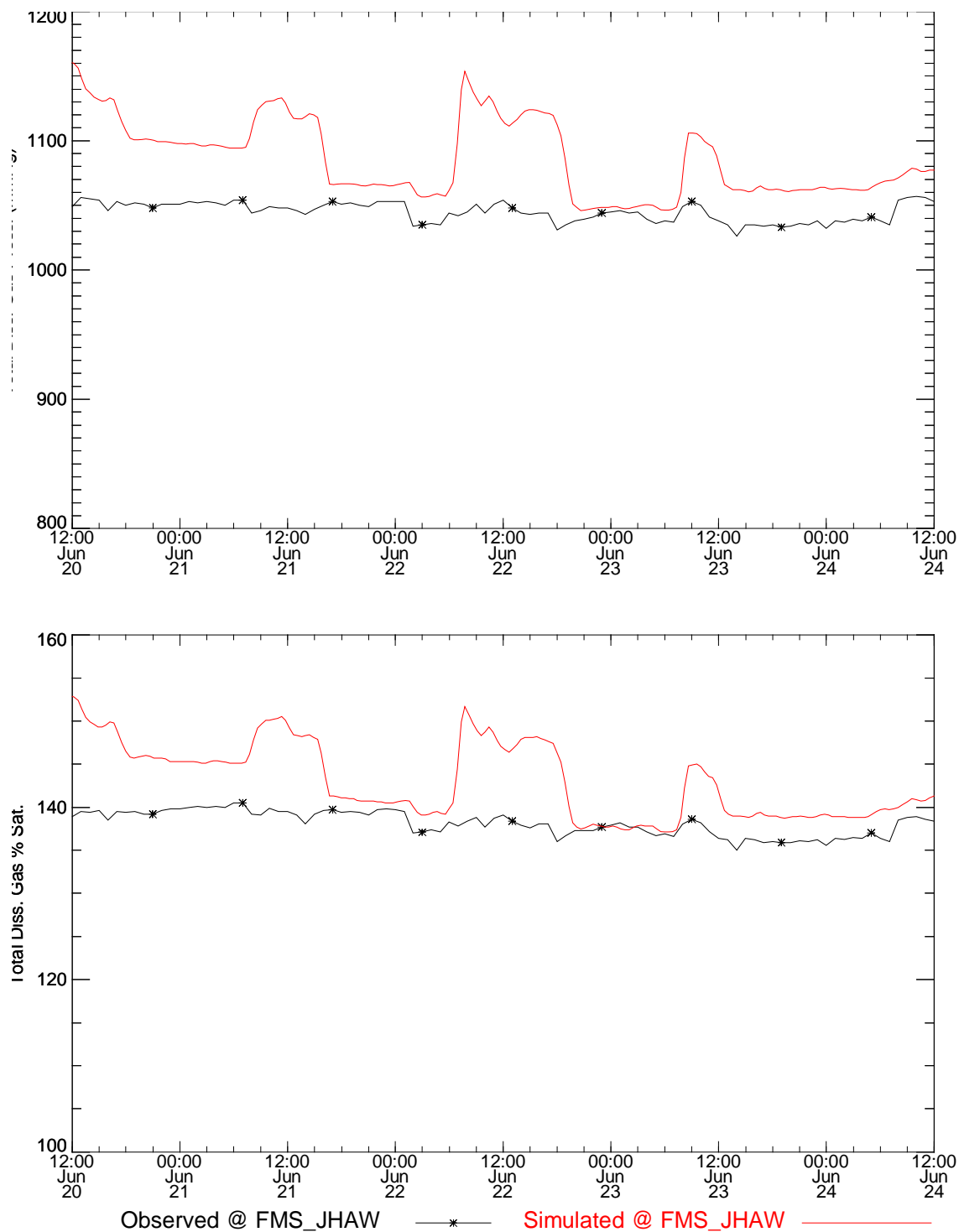
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA21471P	14.84	14.91	0.10	0.16	0.13
TDA21472P	14.78	14.92	0.09	0.16	0.19
TDA21473P	14.81	14.91	0.09	0.16	0.16
TDA21474P	14.86	14.91	0.10	0.16	0.13
TDA21475P	14.63	14.91	0.10	0.17	0.30
Concentration (mg/l)					
TDA21471P	32.72	32.77	0.51	0.58	0.13
TDA21472P	34.46	32.82	0.64	0.60	1.71
TDA21473P	34.29	35.35	1.32	1.18	1.22
TDA21474P	37.52	39.60	0.37	1.13	2.28
TDA21475P	38.64	39.72	0.36	1.07	1.41
Gas Pressure (mmHg)					
TDA21471P	892.62	897.77	13.03	14.93	5.83
TDA21472P	938.42	899.17	17.31	15.36	41.08
TDA21473P	934.27	967.55	35.80	32.33	36.56
TDA21474P	1022.11	1082.29	10.08	31.22	65.38
TDA21475P	1047.63	1085.72	8.78	29.58	45.82
% Saturation					
TDA21471P	117.54	118.19	2.21	2.47	0.75
TDA21472P	123.58	118.37	2.67	2.53	5.45
TDA21473P	123.04	127.38	5.12	4.68	4.79
TDA21474P	134.59	142.49	1.57	4.54	8.59
TDA21475P	137.95	142.95	1.70	4.33	6.02

**Table 66. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 214.7 during the Summer 1997 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA21471P	100	100	100	100
TDA21472P	100	14.88	36.74	37.67
TDA21473P	100	46.05	63.26	63.26
TDA21474P	100	5.12	26.05	26.05
TDA21475P	100	53.49	56.28	56.74



**Figure 114. Temperature and total dissolved gas time series at the JHAW fixed monitor during the Summer 1997 pool study (FMS-BC).**



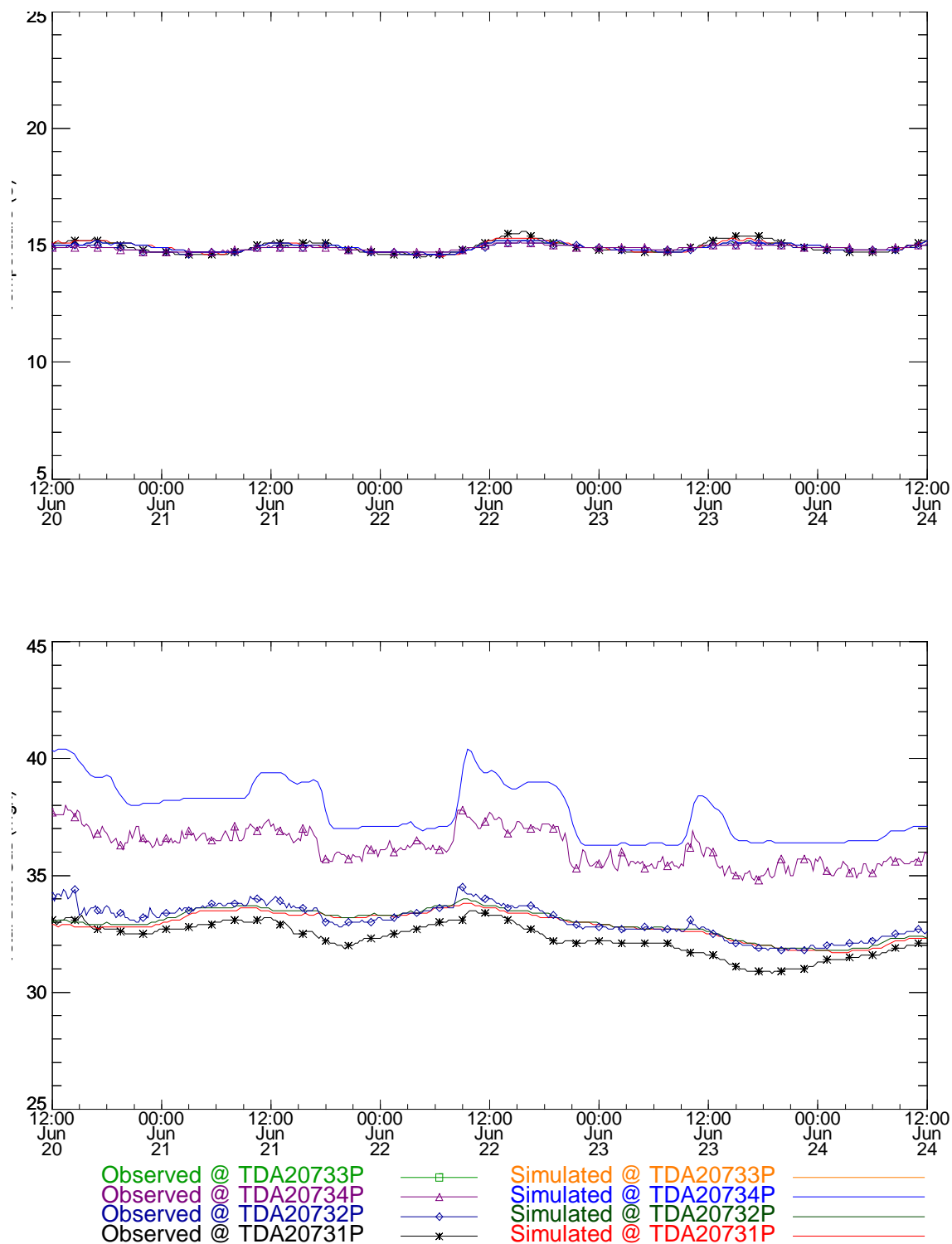
**Figure 115. Total dissolved gas time series comparisons at the JHAW fixed monitor during the Summer 1997 pool study (FMS-BC).**

**Table 67. Statistical summary of measurements and simulations at the JHAW fixed monitor during the Summer 1997 pool study (FMS-BC).**

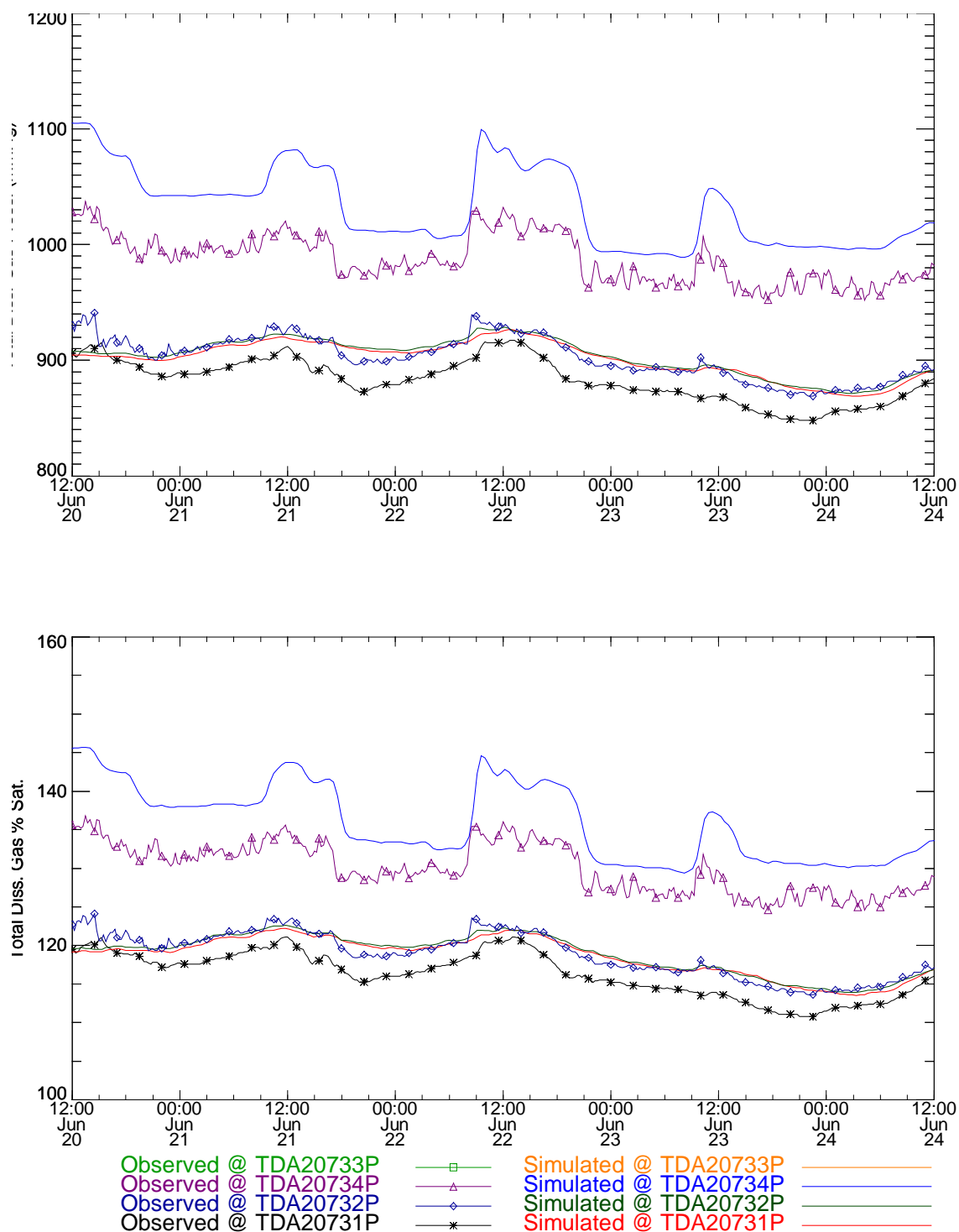
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_JHAW	14.87	14.91	0.10	0.17	0.12
Concentration (mg/l)					
FMS_JHAW	38.34	39.73	0.30	1.06	1.69
Gas Pressure (mmHg)					
FMS_JHAW	1044.81	1085.88	7.18	29.62	49.14
% Saturation					
FMS_JHAW	138.13	142.96	1.38	4.34	6.08

**Table 68. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the JHAW fixed monitor during the Summer 1997 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_JHAW	100	49.30	53.49	55.81



**Figure 116. Temperature and total dissolved gas time series near Columbia River Mile 207.3 during the Summer 1997 pool study (FMS-BC).**



**Figure 117. Total dissolved gas time series comparisons near Columbia River Mile 207.3 during the Summer 1997 pool study (FMS-BC).**

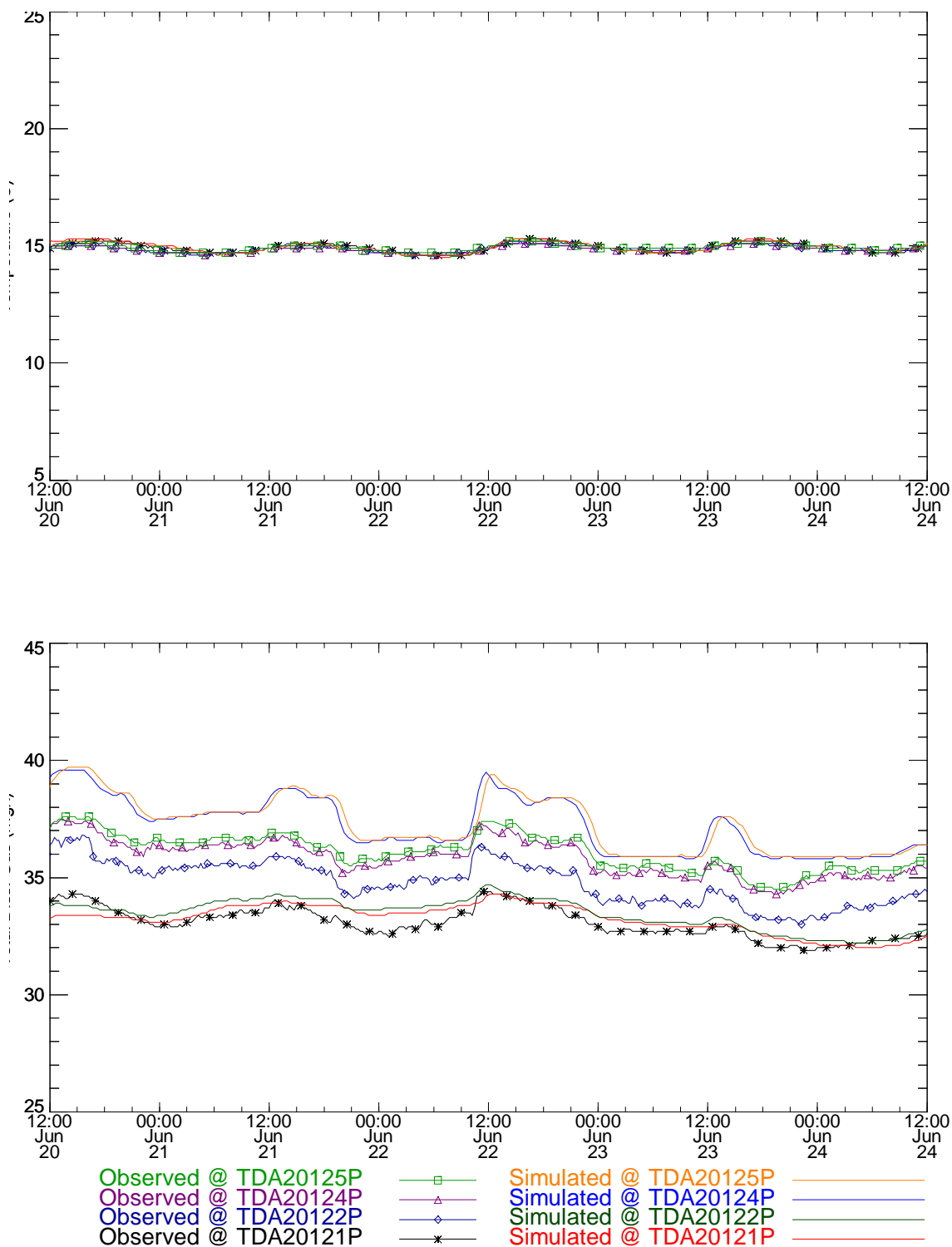
**Table 69. Statistical summary of measurements and simulations at river mile 207.3 during the Summer 1997 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA20731P	14.93	14.93	0.26	0.21	0.11
TDA20732P	14.86	14.92	0.14	0.17	0.10
TDA20734P	14.88	14.92	0.12	0.17	0.12
Concentration (mg/l)					
TDA20731P	32.29	32.88	0.69	0.59	0.68
TDA20732P	33.07	32.97	0.68	0.61	0.30
TDA20734P	36.20	37.72	0.76	1.20	1.64
Gas Pressure (mmHg)					
TDA20731P	882.87	901.07	18.50	15.51	20.28
TDA20732P	902.68	903.33	18.18	15.89	7.16
TDA20734P	987.17	1031.73	20.51	33.59	47.86
% Saturation					
TDA20731P	116.26	118.63	2.91	2.53	2.65
TDA20732P	118.87	118.92	2.88	2.59	0.96
TDA20734P	130.00	135.83	3.16	4.88	6.28

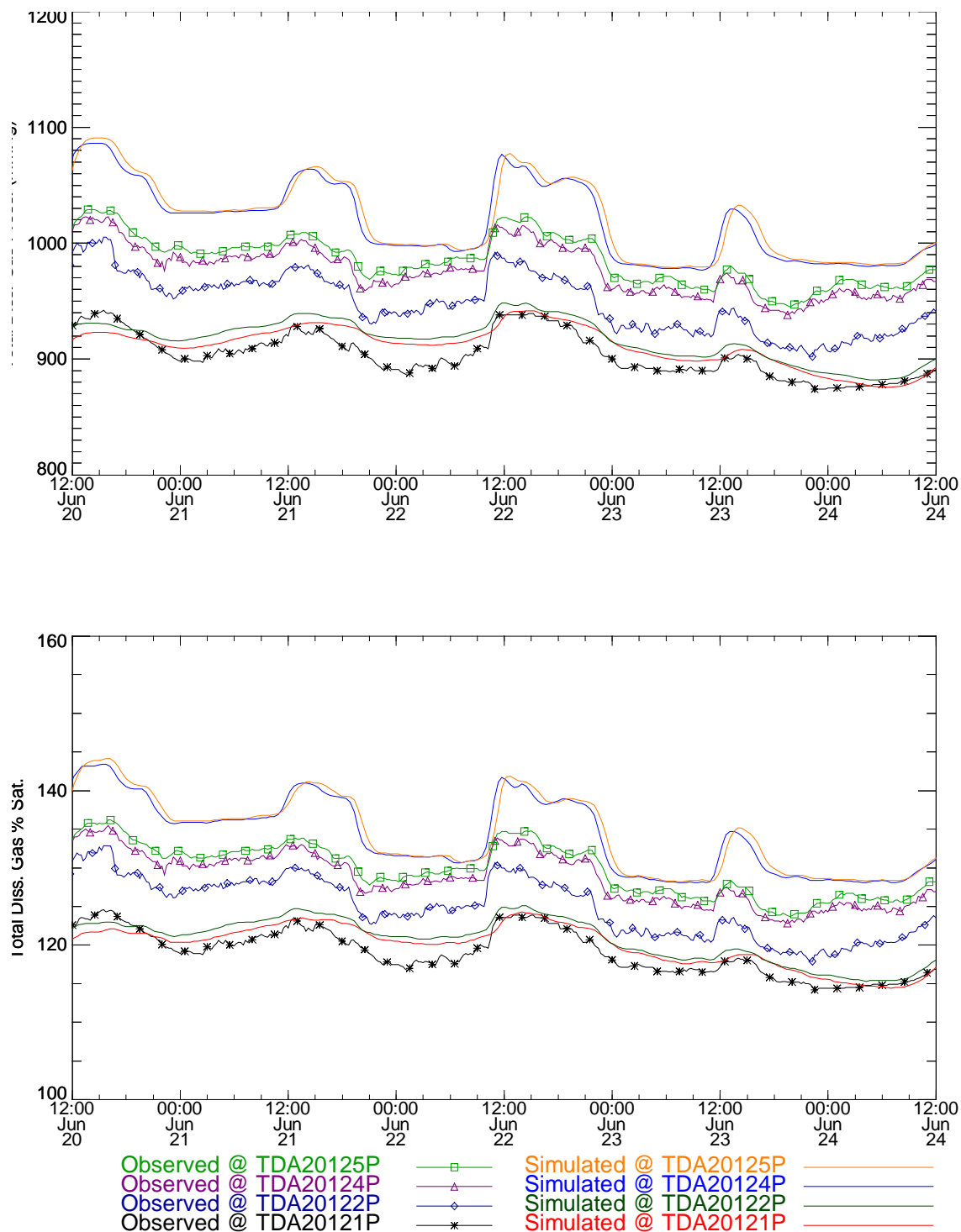
**Table 70. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 207.3 during the Summer 1997 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA20731P	100	89.30	100	100
TDA20732P	100	97.67	100	100
TDA20734P	100	25.58	40.47	40.00





**Figure 118. Temperature and total dissolved gas time series near Columbia River Mile 201.2 during the Summer 1997 pool study (FMS-BC).**



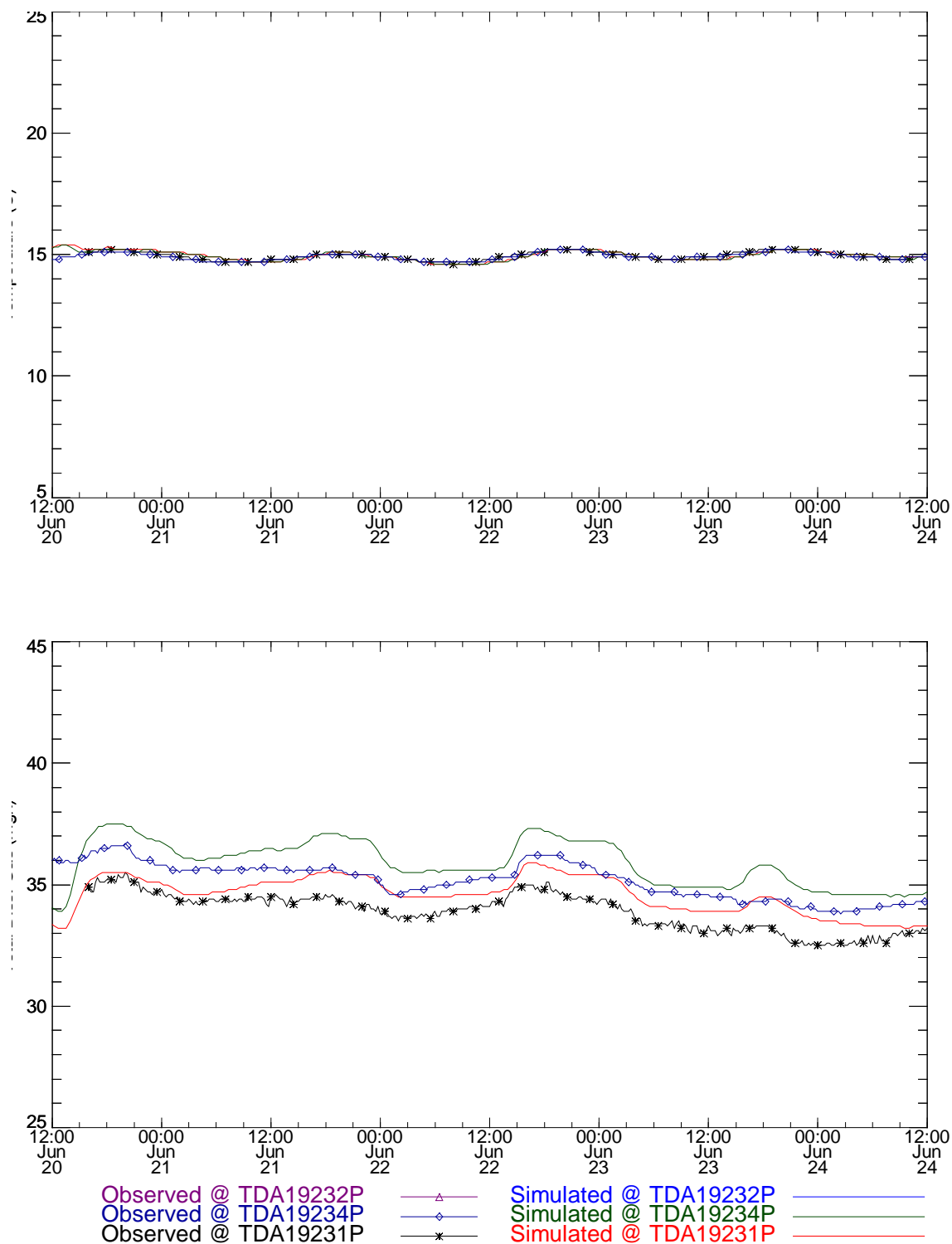
**Figure 119. Total dissolved gas time series comparisons near Columbia River Mile 201.2 during the Summer 1997 pool study (FMS-BC).**

**Table 71. Statistical summary of measurements and simulations at river mile 201.2 during the Summer 1997 pool study (FMS-BC).**

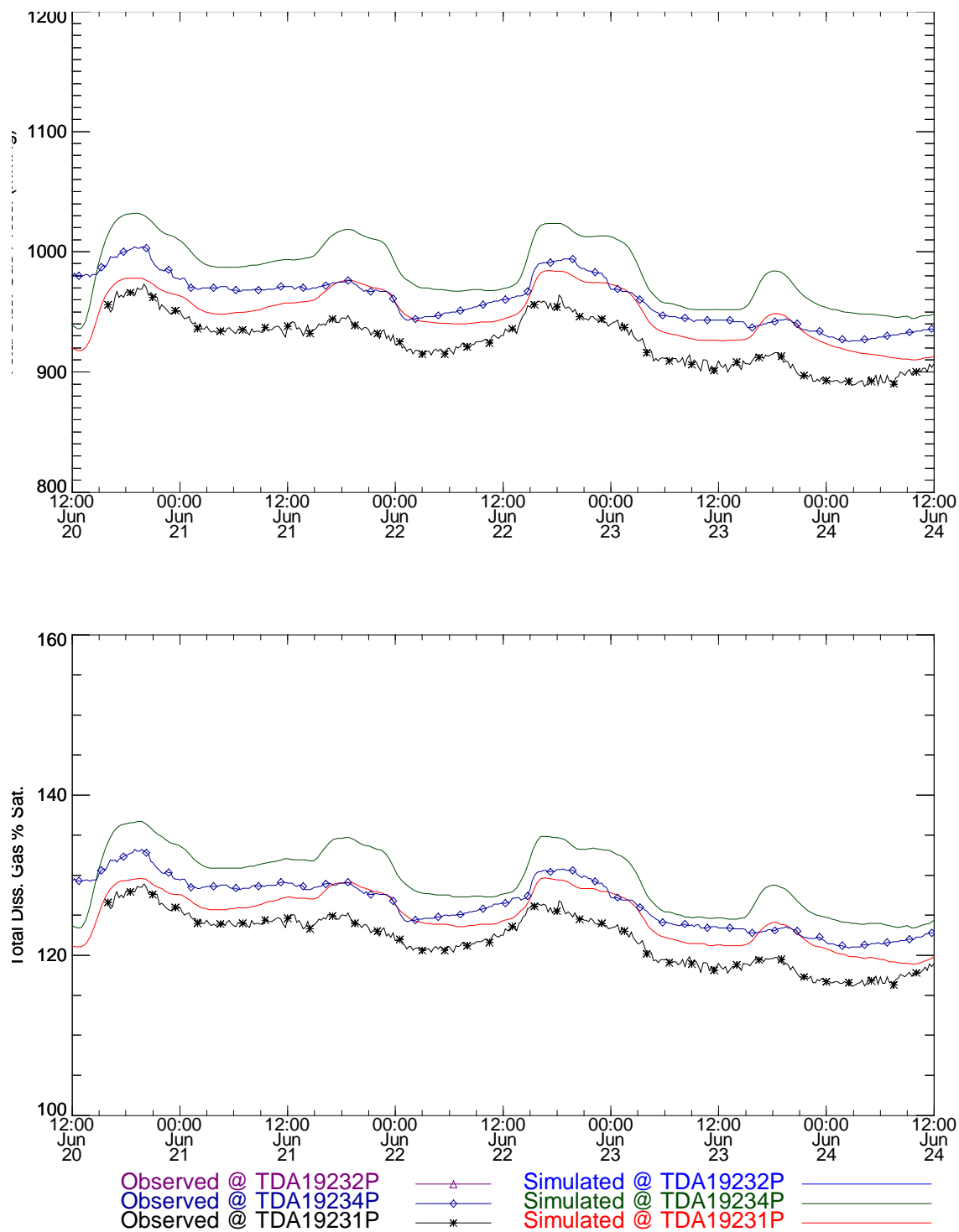
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA20121P	14.93	14.95	0.20	0.22	0.08
TDA20122P	14.85	14.93	0.14	0.20	0.14
TDA20124P	14.86	14.93	0.14	0.18	0.11
TDA20125P	14.92	14.93	0.14	0.19	0.11
Concentration (mg/l)					
TDA20121P	33.07	33.24	0.66	0.62	0.40
TDA20122P	34.78	33.46	0.93	0.65	1.42
TDA20124P	35.83	37.22	0.79	1.17	1.49
TDA20125P	36.10	37.29	0.78	1.18	1.33
Gas Pressure (mmHg)					
TDA20121P	903.85	911.27	18.99	17.05	11.64
TDA20122P	948.42	916.79	25.20	17.74	34.36
TDA20124P	976.91	1018.07	21.39	33.14	43.97
TDA20125P	985.42	1020.37	21.39	33.81	38.87
% Saturation					
TDA20121P	119.02	119.96	2.93	2.71	1.53
TDA20122P	124.89	120.69	3.83	2.82	4.58
TDA20124P	128.65	134.04	3.32	4.84	5.77
TDA20125P	129.77	134.34	3.33	4.93	5.10

**Table 72. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 201.2 during the Summer 1997 study (FMS-BC).**

<b>Station</b>	<b>±1.00 C</b>	<b>±1.00 mg/l</b>	<b>±38.00 mmHg</b>	<b>±5.00% Sat.</b>
TDA20121P	100	100	100	100
TDA20122P	100	35.58	69.35	68.05
TDA20124P	100	36.88	44.42	44.68
TDA20125P	100	43.12	59.48	59.22



**Figure 120. Temperature and total dissolved gas time series near Columbia River Mile 192.3 during the Summer 1997 pool study (FMS-BC).**



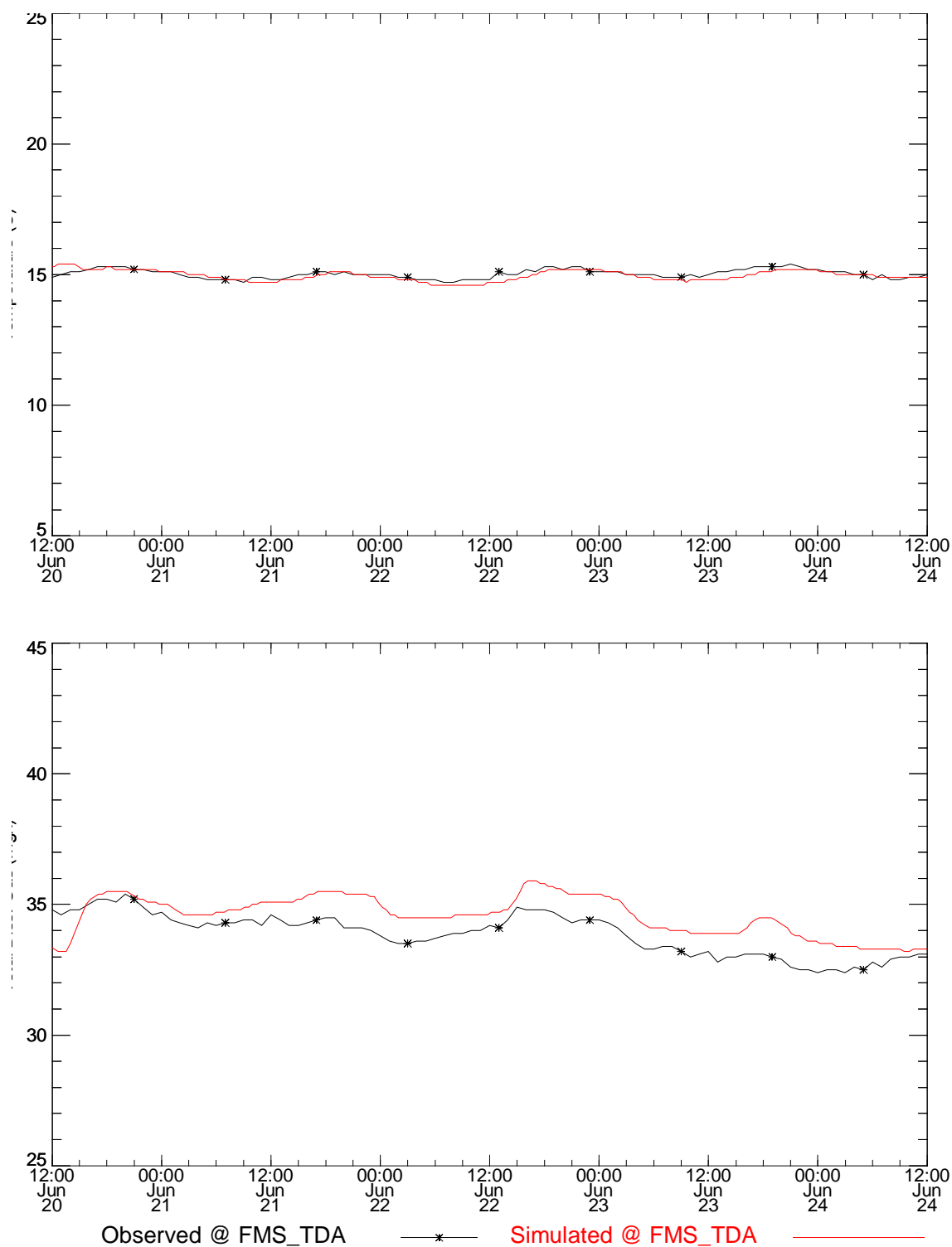
**Figure 121. Total dissolved gas time series comparisons near Columbia River Mile 192.3 during the Summer 1997 pool study (FMS-BC).**

**Table 73. Statistical summary of measurements and simulations at river mile 201.2 during the Summer 1997 pool study (FMS-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
TDA19231P	14.94	14.95	0.16	0.19	0.10
TDA19234P	14.93	14.94	0.15	0.18	0.10
Concentration (mg/l)					
TDA19231P	33.89	34.62	0.77	0.73	0.80
TDA19234P	35.14	35.93	0.74	0.91	0.86
Gas Pressure (mmHg)					
TDA19231P	926.09	948.54	21.09	20.86	23.99
TDA19234P	959.41	983.58	20.57	26.29	26.19
% Saturation					
TDA19231P	121.94	124.86	3.29	3.22	3.13
TDA19234P	126.32	129.48	3.23	3.96	3.43

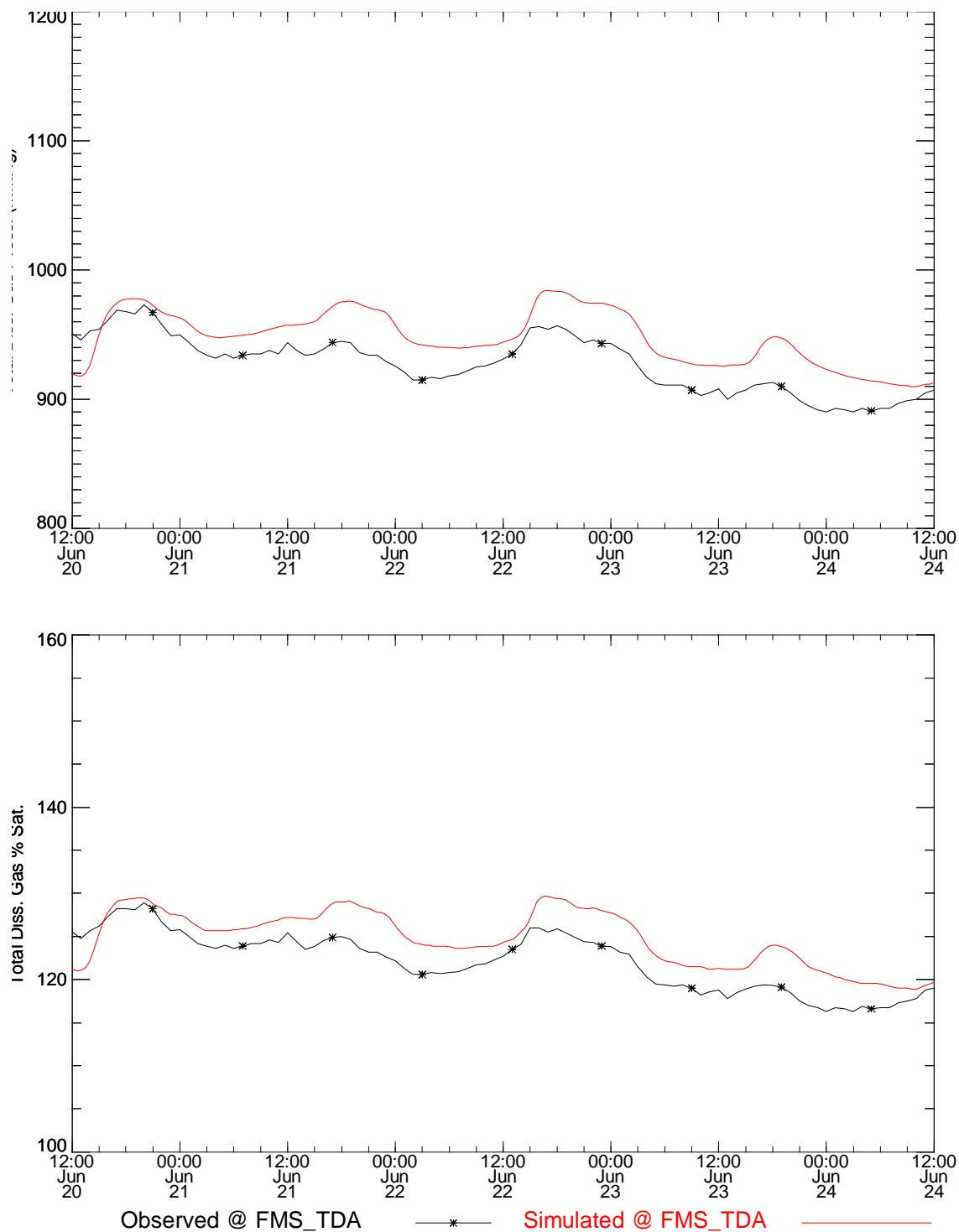
**Table 74. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at river mile 201.2 during the Summer 1997 study (FMS-BC).**

Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
TDA19231P	100	80.76	97.56	97.56
TDA19234P	100	73.98	88.08	88.62



**Figure 122. Temperature and total dissolved gas time series at the TDA fixed monitor during the Summer 1997 pool study (FMS-BC).**





**Figure 123. Total dissolved gas time series comparisons at the TDA fixed monitor during the Summer 1997 pool study (FMS-BC).**

**Table 75. Statistical summary of measurements and simulations at the TDA fixed monitor during the Summer 1997 pool study (FMS-BC).**

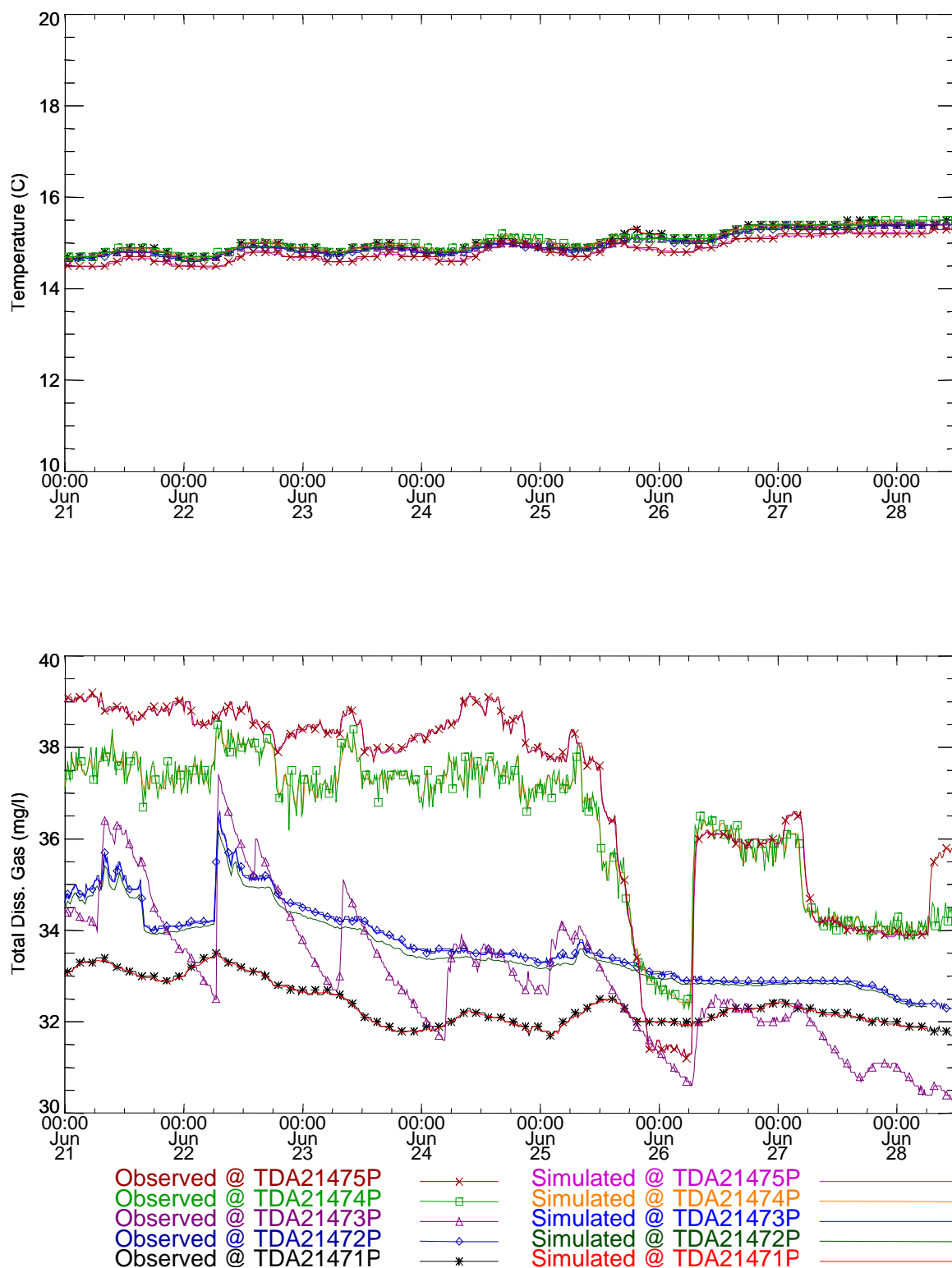
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature (°C)					
FMS_TDA	15.03	14.96	0.17	0.20	0.15
Concentration (mg/l)					
FMS_TDA	33.87	34.59	0.78	0.74	0.88
Gas Pressure (mmHg)					
FMS_TDA	927.42	947.94	21.61	20.75	23.78
% Saturation					
FMS_TDA	122.13	124.80	3.35	3.17	3.12

**Table 76. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the TDA fixed monitor during the Summer 1997 study (FMS-BC).**

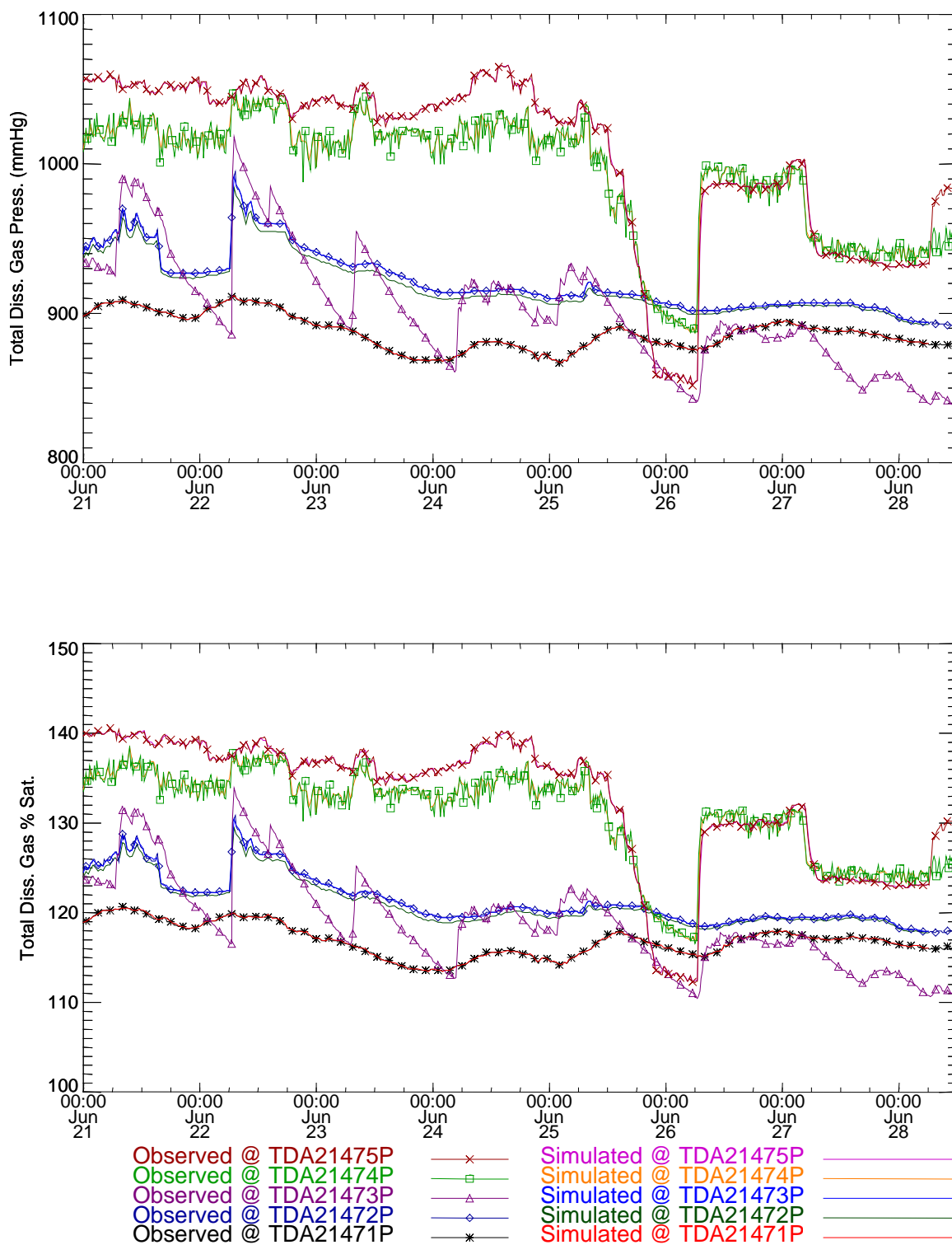
Station	±1.00 C	±1.00 mg/l	±38.00 mmHg	±5.00% Sat.
FMS_TDA	100	72.09	99.07	100

*Boundary Conditions using Temporary Monitored Field Data Boundary Conditions*

The following figures and tables show the comparison between the model and field using the temporary field monitor data as the upstream boundary conditions.



**Figure 124. Temperature and total dissolved gas time series near Columbia River Mile 214.7 during the Summer 1997 pool study (TM-BC).**



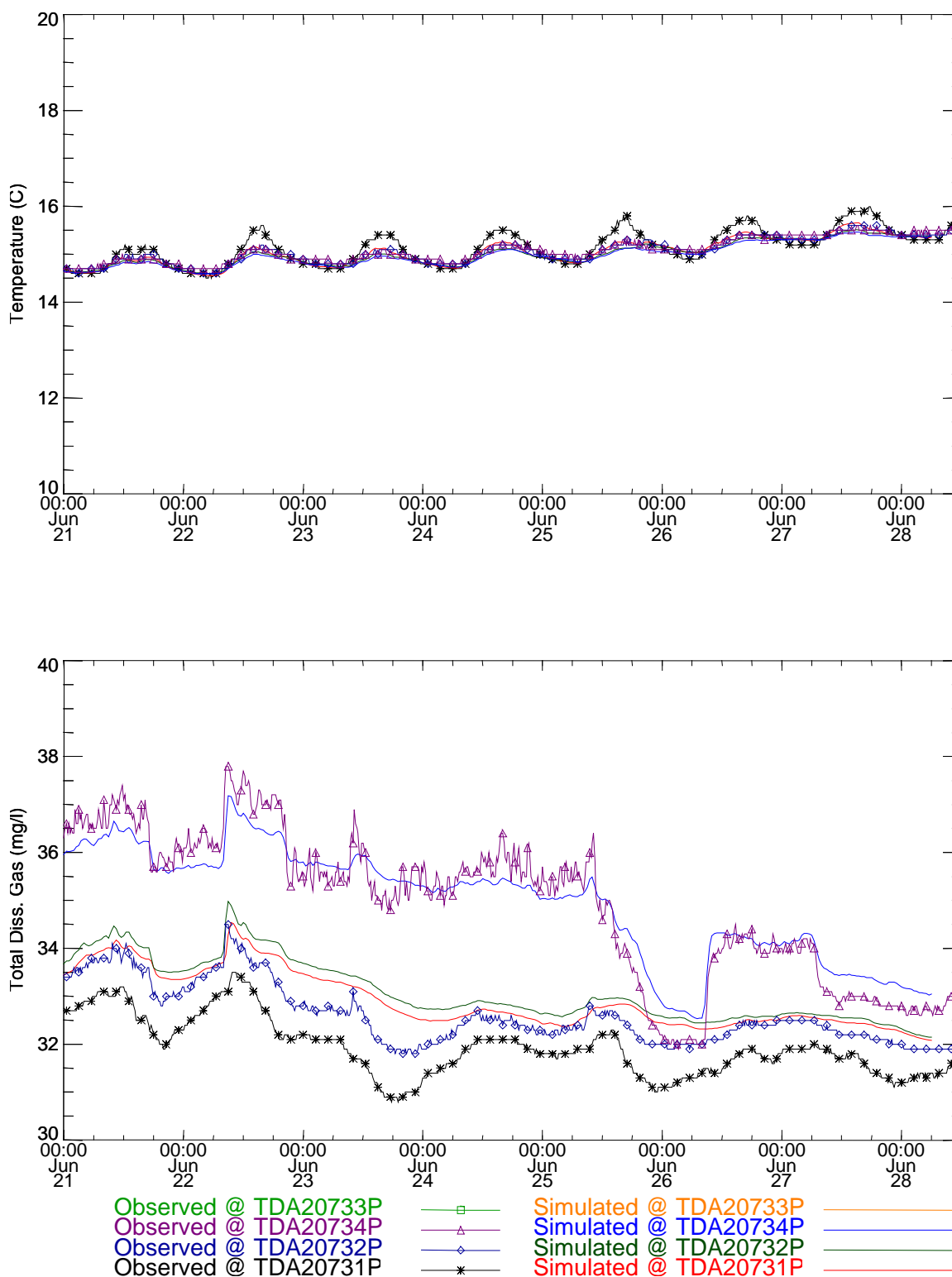
**Figure 125. Total dissolved gas time series comparisons at the river mile 214.7 during the Summer 1997 pool study (TM-BC).**

**Table 77. Statistical summary of measurements and simulations at Columbia river mile 214.7 during the Summer 1997 pool study (TM-BC).**

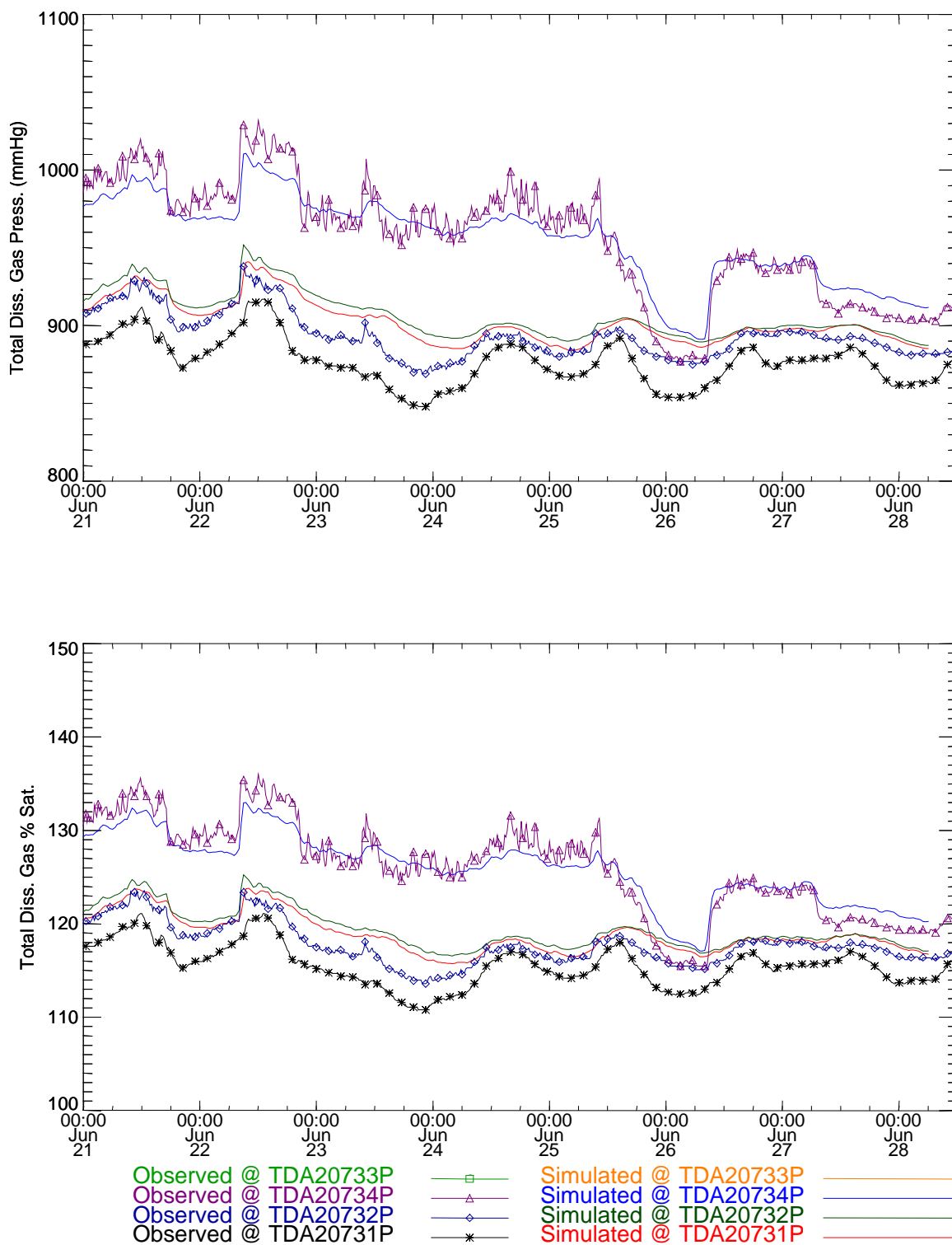
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA21471P	15.03	15.03	0.24	0.24	0.03
TDA21472P	14.97	14.97	0.23	0.23	0.03
TDA21473P	15.01	14.97	0.23	0.23	0.05
TDA21474P	15.06	15.05	0.24	0.23	0.03
TDA21475P	14.83	14.83	0.23	0.23	0.03
Concentration					
TDA21471P	32.4	32.39	0.49	0.49	0.03
TDA21472P	33.72	33.58	0.86	0.81	0.16
TDA21473P	33.08	33.7	1.52	0.85	1.05
TDA21474P	36.38	36.37	1.59	1.59	0.05
TDA21475P	36.98	36.97	2.21	2.21	0.04
Gas Pressure					
TDA21471P	887.67	887.68	11.79	11.78	0.1
TDA21472P	921.99	918.71	20.03	18.88	3.58
TDA21473P	905.42	922	38.34	20.01	28.24
TDA21474P	995.5	995.62	39.92	39.92	1.29
TDA21475P	1007.04	1007.11	56.42	56.39	0.66
% Saturation					
TDA21471P	116.94	116.94	1.84	1.85	0.11
TDA21472P	121.46	121.03	2.74	2.61	0.48
TDA21473P	119.28	121.46	5.15	2.74	3.73
TDA21474P	131.13	131.15	5.15	5.15	0.21
TDA21475P	132.65	132.66	7.35	7.34	0.15

**Table 78. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at Columbia river mile 214.7 during the Summer 1997 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA21471P	100	100	100	100
TDA21472P	100	100	100	100
TDA21473P	100	65.33	77.08	77.08
TDA21474P	100	100	100	100
TDA21475P	100	100	100	100



**Figure 126. Temperature and total dissolved gas time series near Columbia River Mile 207.3 during the Summer 1997 pool study (TM-BC).**



**Figure 127. Total dissolved gas time series comparisons at the river mile 207.3 during the Summer 1997 pool study (TM-BC).**

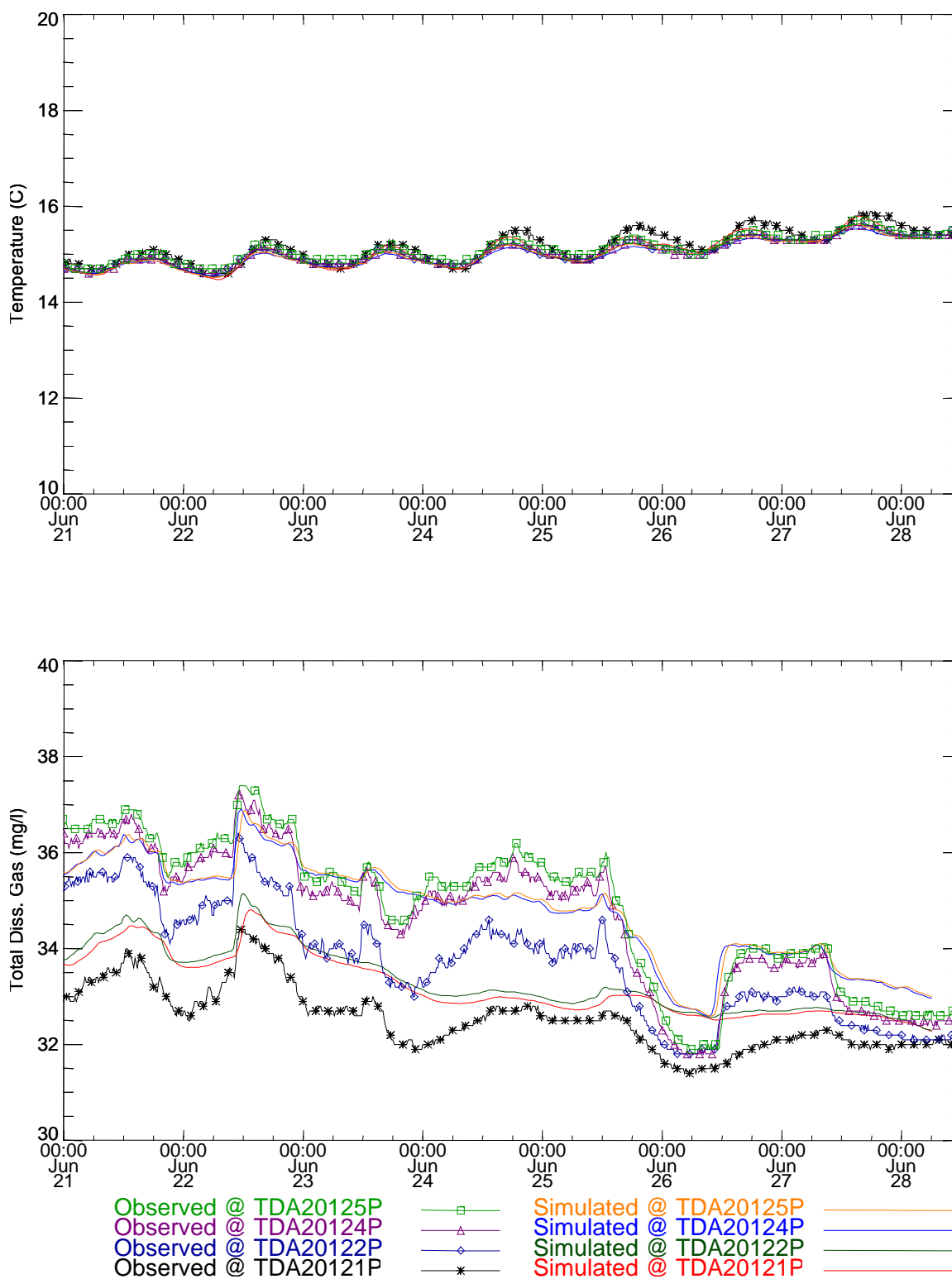
**Table 79. Statistical summary of measurements and simulations at Columbia river mile 207.3 during the Summer 1997 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA20731P	15.13	15.04	0.35	0.28	0.17
TDA20732P	15.06	15.01	0.26	0.25	0.07
TDA20734P	15.08	14.98	0.24	0.24	0.1
Concentration					
TDA20731P	31.94	32.92	0.6	0.6	1.04
TDA20732P	32.63	33.1	0.63	0.65	0.53
TDA20734P	34.96	34.95	1.5	1.14	0.44
Gas Pressure					
TDA20731P	876.83	902.31	15.29	13.7	27.08
TDA20732P	894.09	906.39	14.94	14.77	13.95
TDA20734P	957.4	955.79	37.5	27.47	12.28
% Saturation					
TDA20731P	115.51	118.87	2.29	2.03	3.58
TDA20732P	117.78	119.41	2.24	2.14	1.84
TDA20734P	126.12	125.91	4.96	3.62	1.63

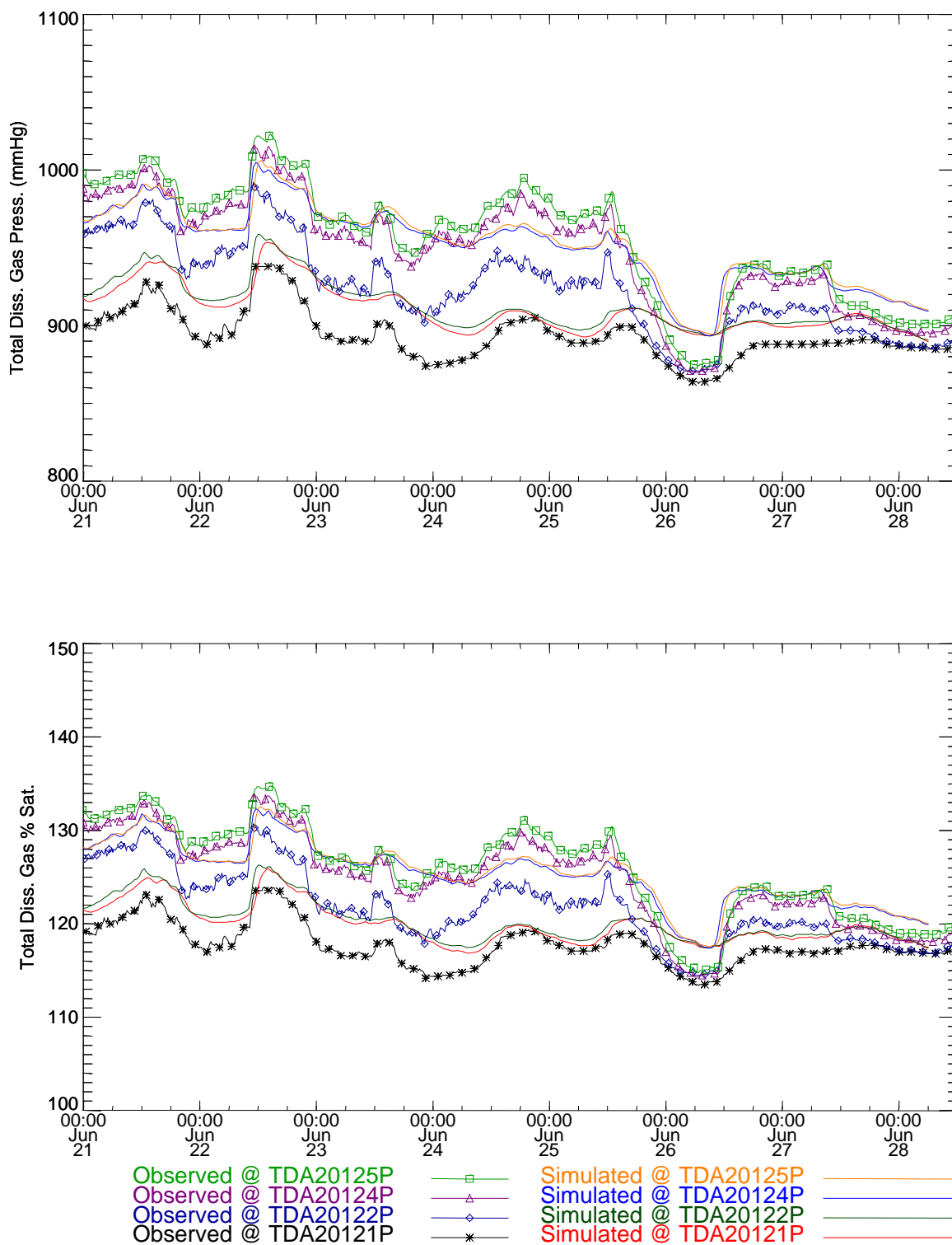
**Table 80. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at Columbia River mile 207.3 during the Summer 1997 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA20731P	100	58.17	89.97	89.11
TDA20732P	100	96.28	100	100
TDA20734P	100	99.71	100	100





**Figure 128. Temperature and total dissolved gas time series near Columbia River Mile 201.2 during the Summer 1997 pool study (TM-BC).**



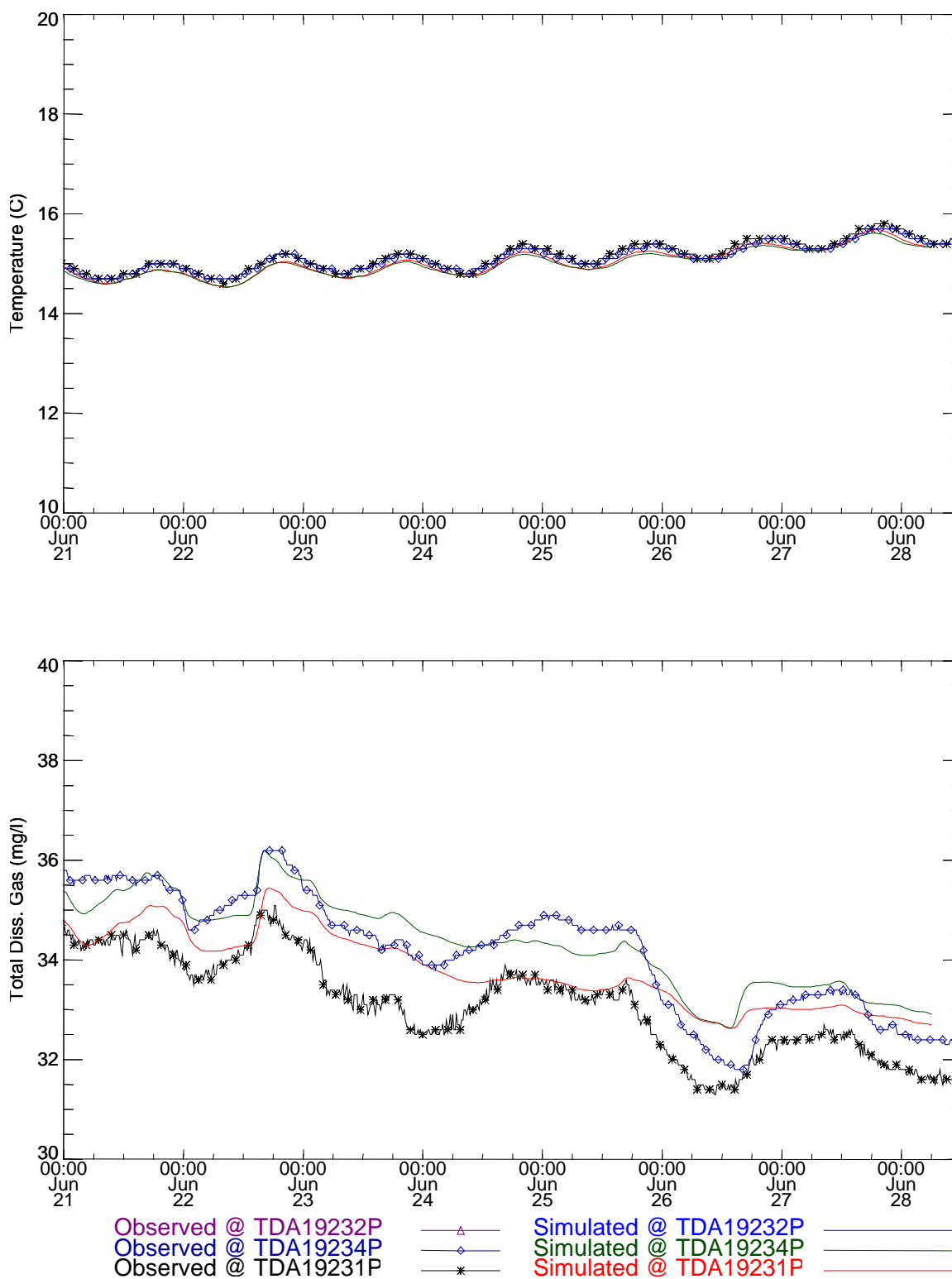
**Figure 129. Total dissolved gas time series comparisons at the river mile 201.2 during the Summer 1997 pool study (TM-BC).**

**Table 81. Statistical summary of measurements and simulations at Columbia river mile 201.2 during the Summer 1997 pool study (TM-BC).**

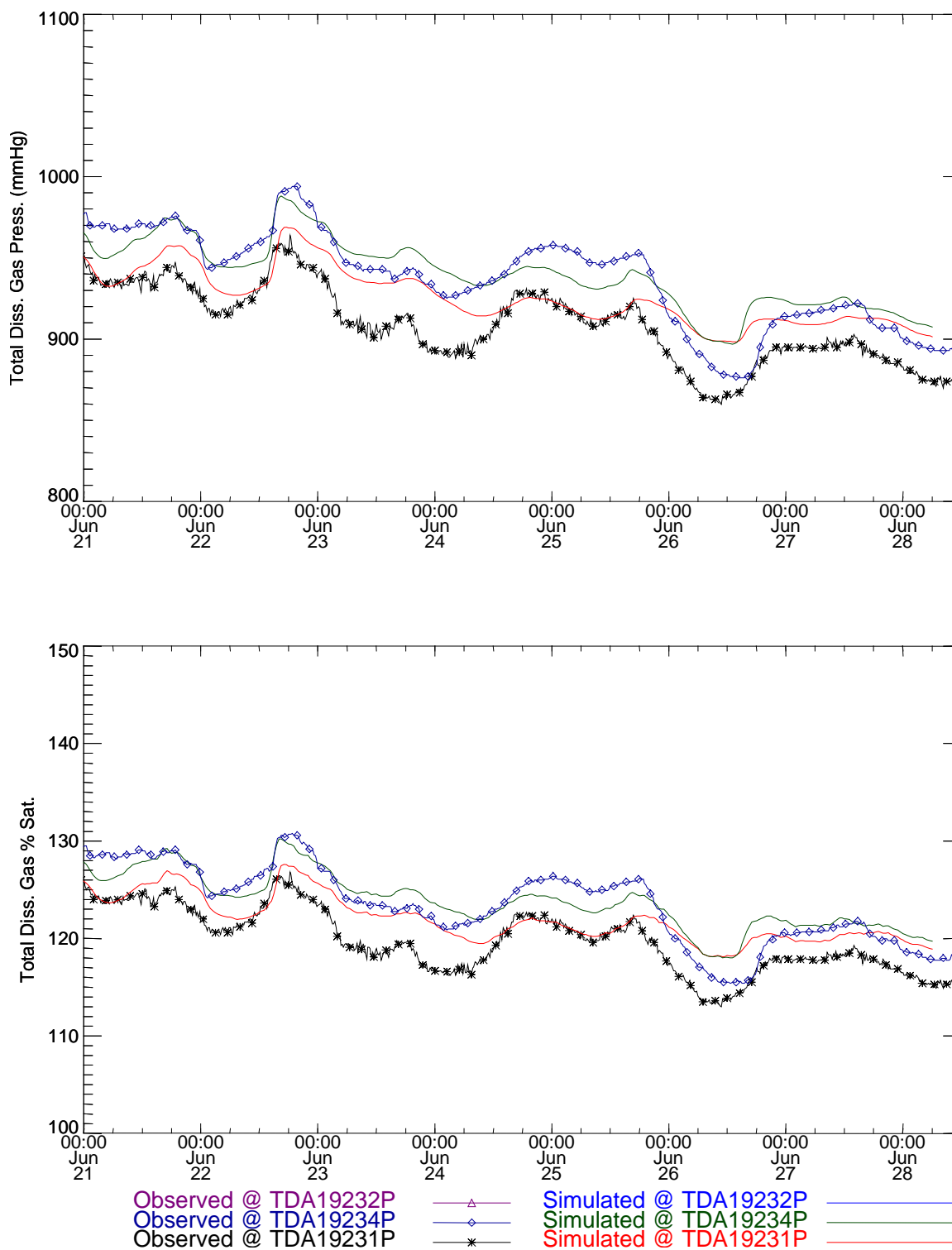
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA20121P	15.17	15.06	0.33	0.31	0.13
TDA20122P	15.06	15.03	0.26	0.27	0.06
TDA20124P	15.07	15	0.26	0.26	0.08
TDA20125P	15.12	15.02	0.26	0.27	0.12
Concentration					
TDA20121P	32.54	33.19	0.66	0.66	0.73
TDA20122P	33.72	33.3	1.19	0.7	0.78
TDA20124P	34.59	34.71	1.47	1.09	0.51
TDA20125P	34.84	34.75	1.51	1.09	0.54
Gas Pressure					
TDA20121P	893.62	910.02	15.7	15.14	18.54
TDA20122P	923.67	912.38	29.02	16	21.25
TDA20124P	947.14	949.77	36.46	25.9	13.77
TDA20125P	955.03	951.2	37.67	26.04	15.17
% Saturation					
TDA20121P	117.73	119.89	2.28	2.15	2.45
TDA20122P	121.69	120.2	3.94	2.25	2.81
TDA20124P	124.78	125.12	4.85	3.43	1.82
TDA20125P	125.82	125.31	5.01	3.46	2.01

**Table 82. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at Columbia river mile 201.2 during the Summer 1997 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA20121P	100	78.92	100	100
TDA20122P	100	75.31	96.39	96.39
TDA20124P	100	99.17	99.86	100
TDA20125P	100	98.34	100	100



**Figure 130. Temperature and total dissolved gas time series near Columbia River Mile 192.3 during the Summer 1997 pool study (TM-BC).**



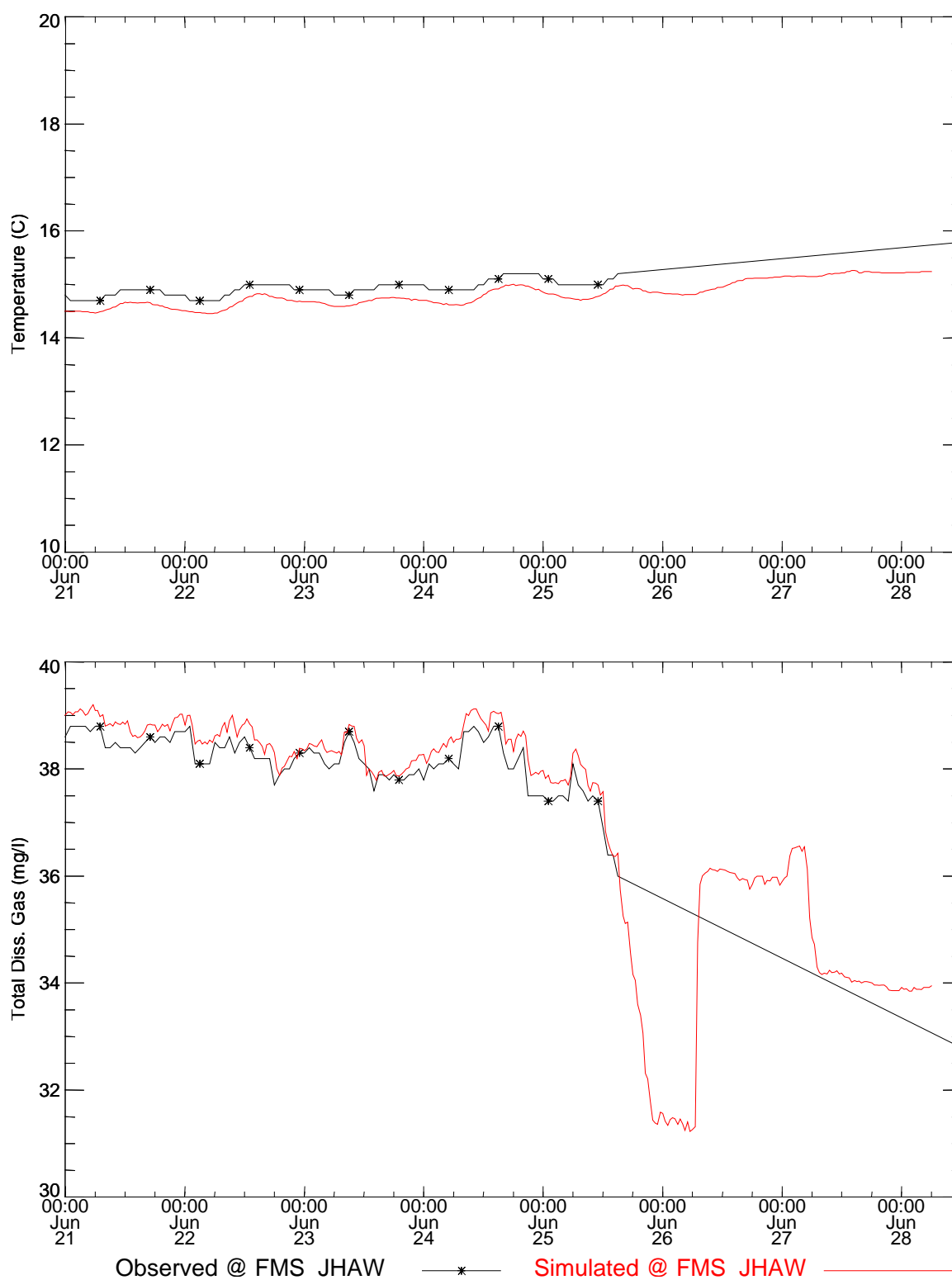
**Figure 131. Total dissolved gas time series comparisons at the river mile 192.3 during the Summer 1997 pool study (TM-BC).**

**Table 83. Statistical summary of measurements and simulations at Columbia river mile 192.3 during the Summer 1997 pool study (TM-BC).**

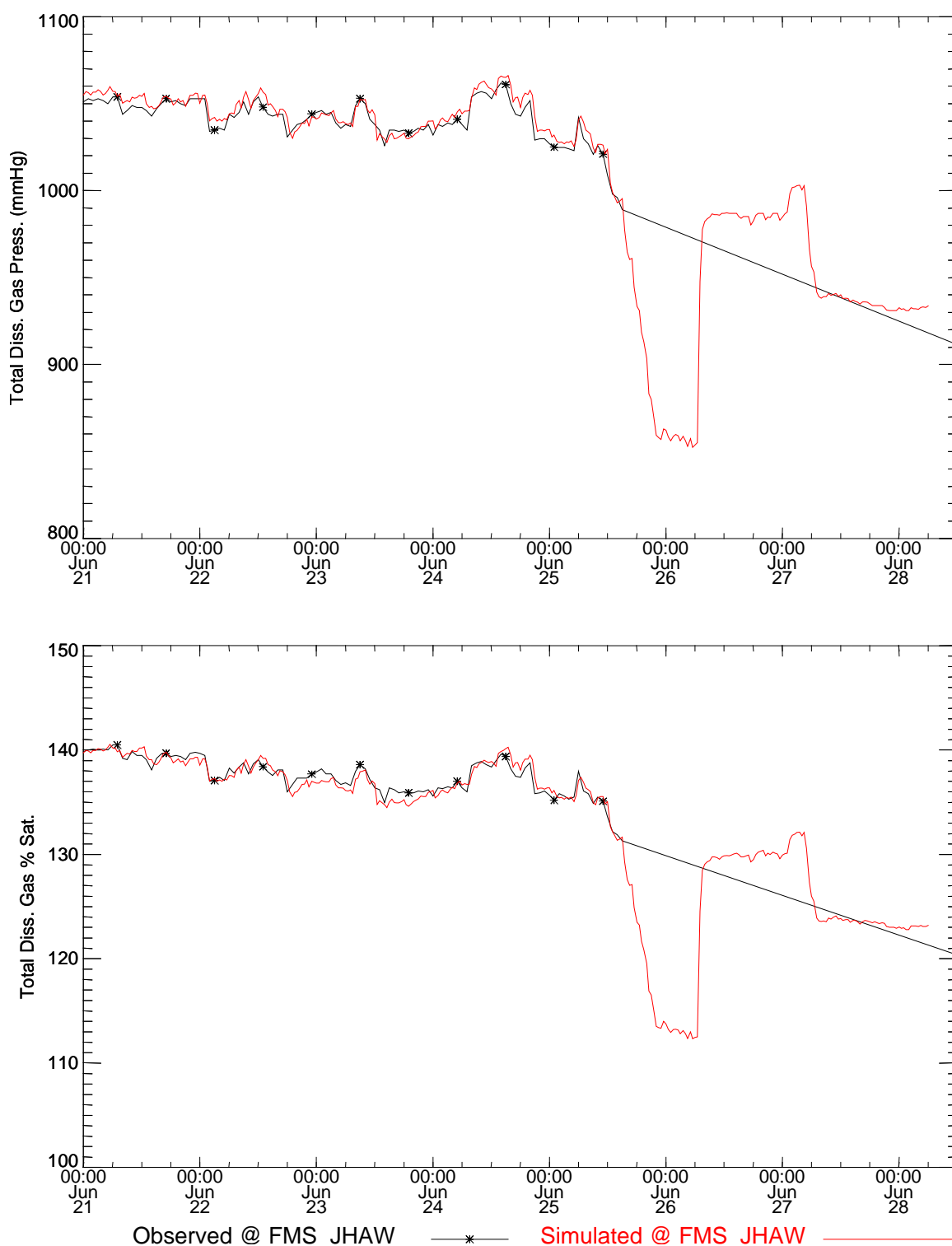
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
TDA19231P	15.15	15.04	0.28	0.28	0.12
TDA19234P	15.12	15.02	0.26	0.27	0.12
Concentration					
TDA19231P	33.08	33.75	0.98	0.77	0.8
TDA19234P	34.15	34.28	1.19	0.91	0.46
Gas Pressure					
TDA19231P	908.23	924.78	23.44	17.3	20.54
TDA19234P	936.49	938.62	28.97	21.07	12.42
% Saturation					
TDA19231P	119.66	121.83	3.23	2.34	2.71
TDA19234P	123.38	123.65	3.91	2.82	1.64

**Table 84. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at Columbia river mile 192.3 during the Summer 1997 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
TDA19231P	100	69.9	99.03	99.03
TDA19234P	100	97.5	98.75	98.75



**Figure 132. Temperature and total dissolved gas time series near fixed monitor JHAW during the Summer 1997 pool study (TM-BC).**



**Figure 133. Total dissolved gas time series comparisons at fixed monitor JHAW during the Summer 1997 pool study (TM-BC).**

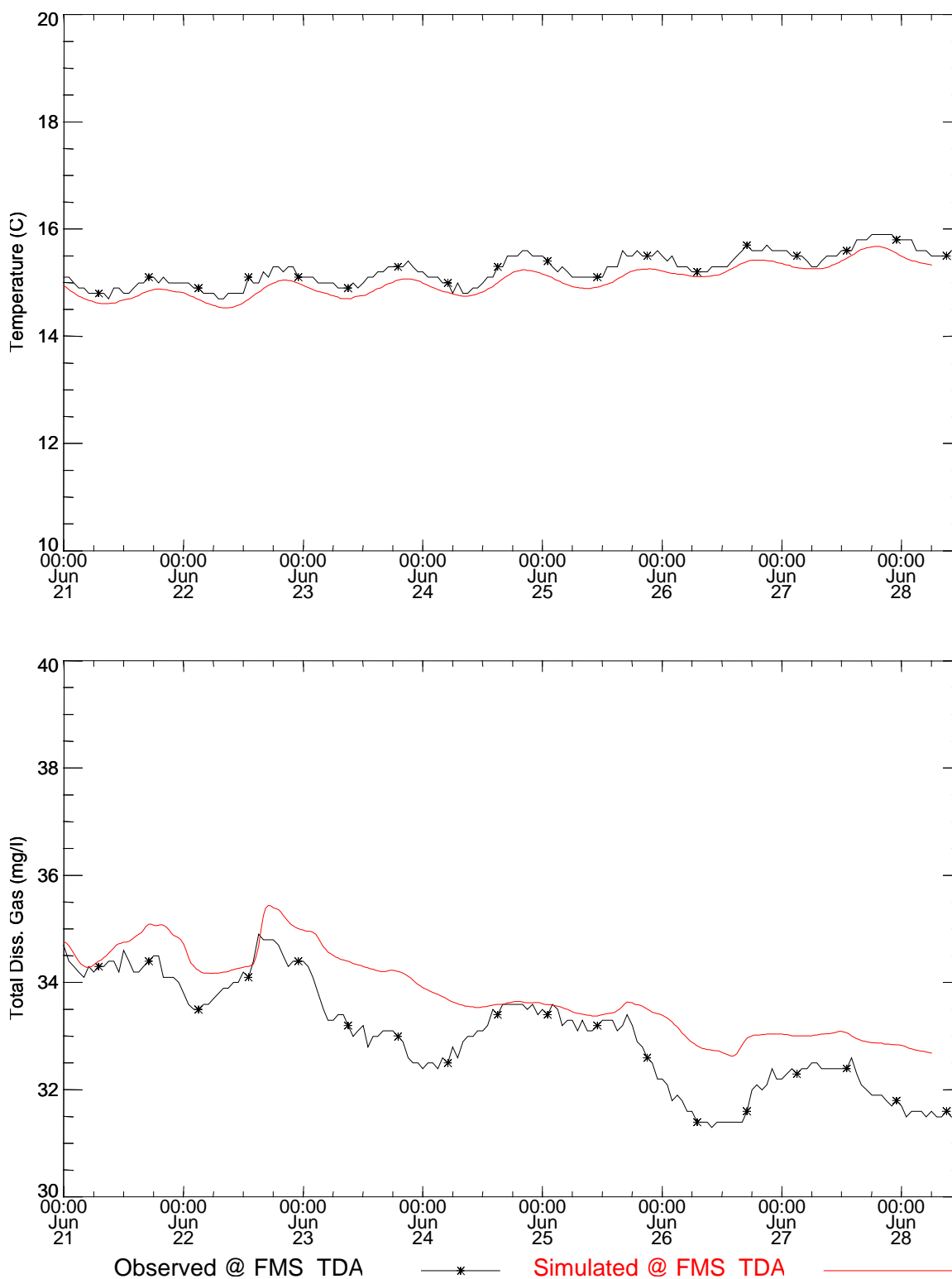


**Table 85. Statistical summary of measurements and simulations at fixed monitor JHAW during the Summer 1997 pool study (TM-BC).**

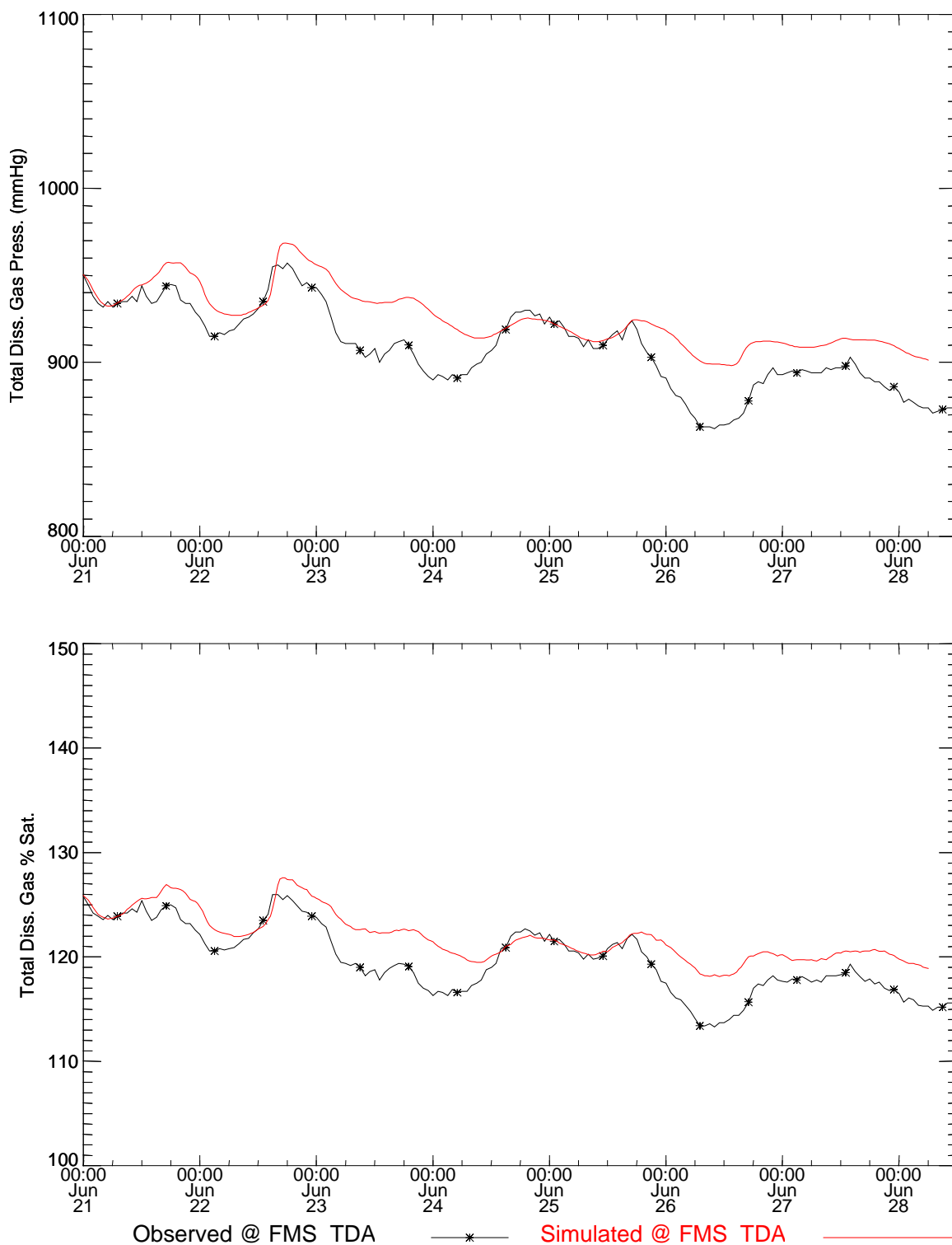
Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_JHAW	15.12	14.83	0.3	0.23	0.31
Concentration					
FMS_JHAW	36.84	36.97	1.86	2.21	1.18
Gas Pressure					
FMS_JHAW	1009.19	1007.1	44.83	56.4	32.42
% Saturation					
FMS_JHAW	133.46	132.66	5.84	7.34	4.38

**Table 86. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the JHAW fixed monitor during the Summer 1997 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_JHAW	100	80.8	89.97	89.97



**Figure 134. Temperature and total dissolved gas time series near fixed monitor TDA during the Summer 1997 pool study (TM-BC).**



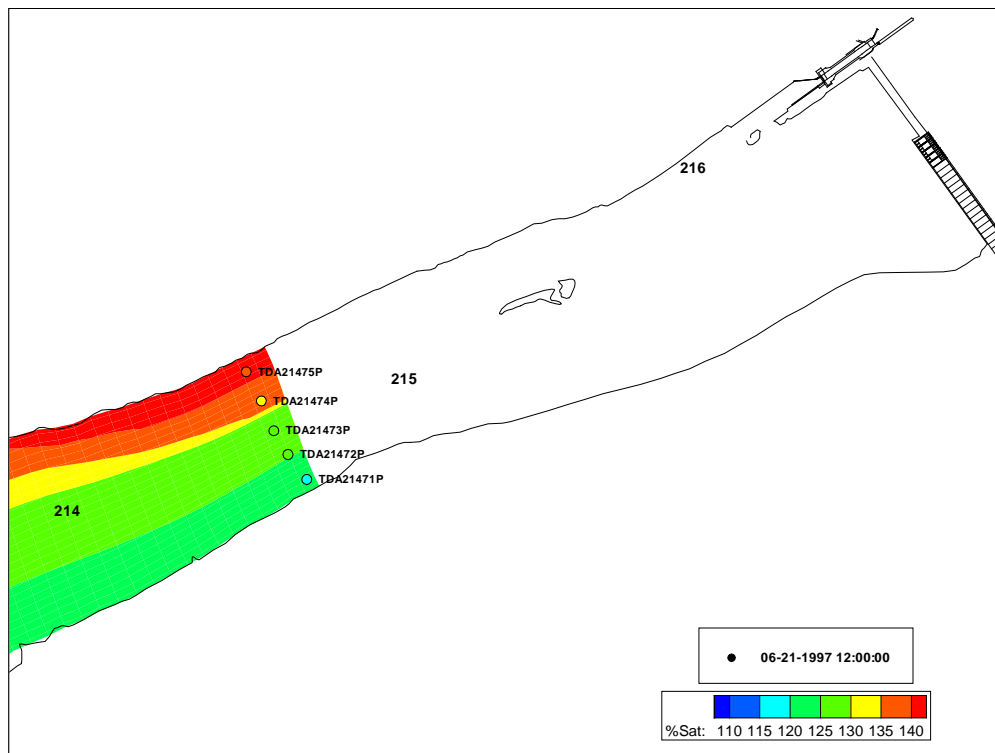
**Figure 135. Total dissolved gas time series comparisons at fixed monitor TDA during the Summer 1997 pool study (TM-BC).**

**Table 87. Statistical summary of measurements and simulations at fixed monitor TDA during the Summer 1997 pool study (TM-BC).**

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_TDA	15.24	15.03	0.3	0.28	0.22
Concentration					
FMS_TDA	33.06	33.79	0.96	0.76	0.86
Gas Pressure					
FMS_TDA	909.31	925.49	23.11	17.02	20.38
% Saturation					
FMS_TDA	119.79	121.92	3.2	2.32	2.69

**Table 88. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at the TDA fixed monitor during the Summer 1997 study (TM-BC).**

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_TDA	100	66.76	98.57	99.71



**Figure 136. Spatial distribution of dissolved gas near Columbia river mile 216 during the Summer 1997 study period.**

---

## 2 References

National Oceanic and Atmospheric Administration (NOAA), 1983. *Columbia River: Lake Celilo*. Nautical Chart 18533, 9<sup>th</sup> Ed., National Ocean Service, Riverdale, Maryland.

National Oceanic and Atmospheric Administration (NOAA), 1991. *Columbia River: Vancouver to Bonneville*. Nautical Chart 18531, 17<sup>th</sup> Ed., National Ocean Service, Riverdale, Maryland.

Richmond, M.C., W.A. Perkins, and T.D. Scheibe. 1998. *Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 1: Summary and Model Formulation*. Draft Final Report submitted to U.S. Army Corps of Engineers, Walla Walla District. Battelle Pacific Northwest Division, Richland, Washington.

Schneider, M.L., and S.C. Wilhelms, 1997. *Total Dissolved Gas Production at Spillways on the Snake and Lower Columbia Rivers*. Memorandum for Record, CEWES-HS-L, U.S. Army Corps of Engineers, Available (limited access): [limnos.wes.army.mil](http://limnos.wes.army.mil) Directory: /data3/dgas/Documents/reports/ File: dgasprod.exe.

Steinbrenner J.P., and J.R. Chawner, 1995. *The GRIDGEN Version 9 Multiple Block Grid Generation Software*. MDA Engineering, Inc., Arlington, Texas.

U.S. Geological Survey (USGS), 1995. *Metadata for 1-degree Digital Elevation Models*. [online report]. Available Online URL: <http://nsdi.usgs.gov/> File: [nsdi/wais/maps/dem1deg.HTML](http://nsdi/wais/maps/dem1deg.HTML).

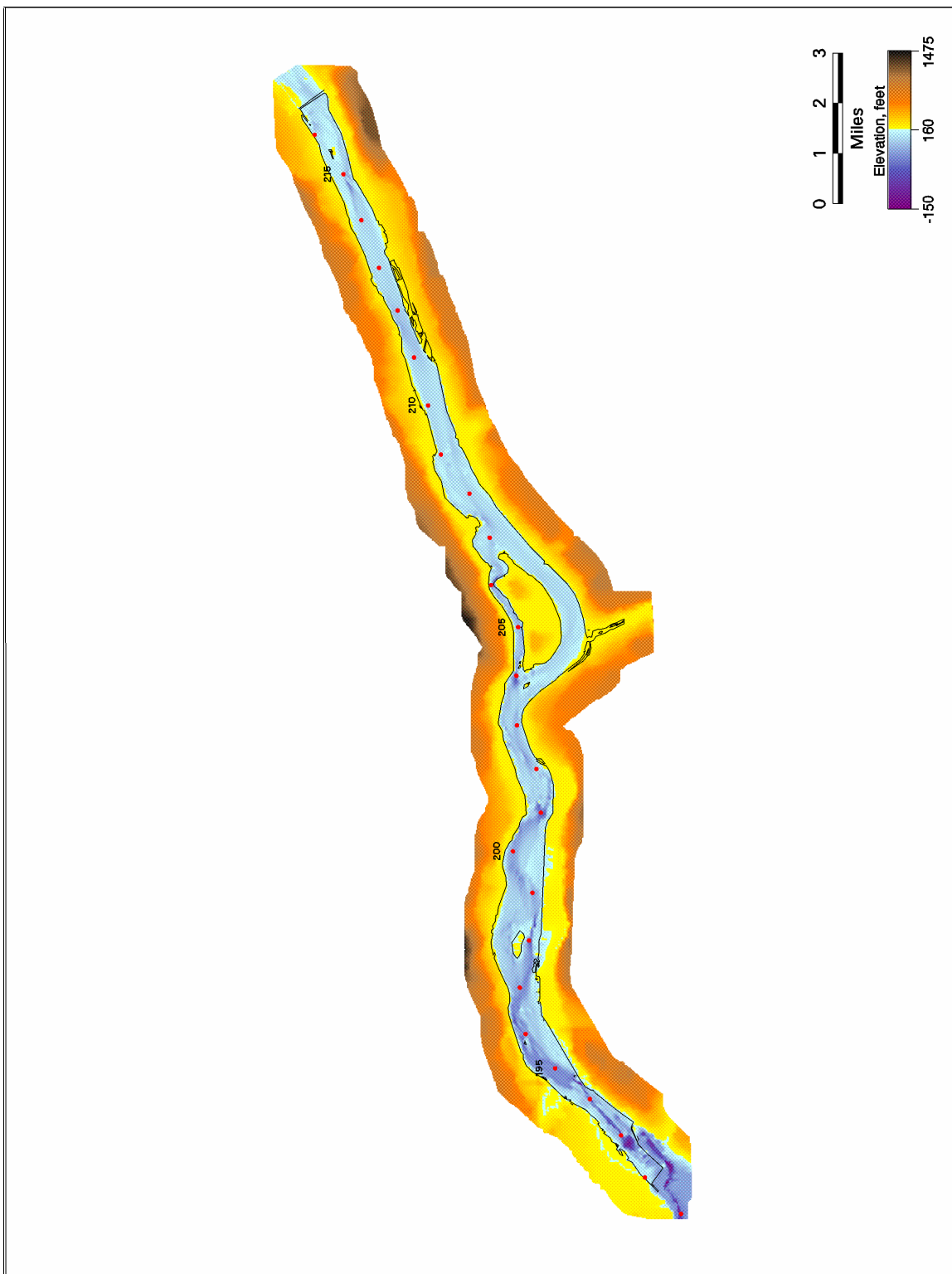
## Appendix A. The Dalles Pool Data Sources

### A.1 Bathymetry

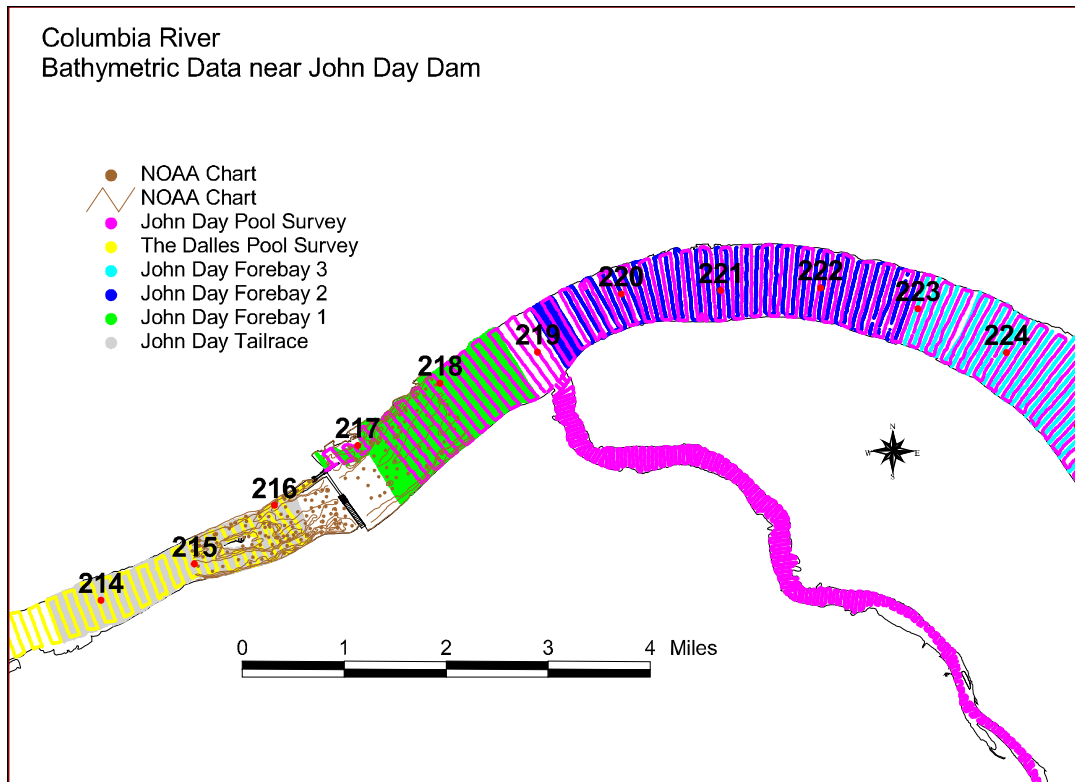
Bathymetric data for the Columbia River was gathered from the various sources shown in Table 89. The primary source was The Dalles pool survey, during which elevations were measured at a relatively fine spacing over the entire pool, except in the restricted areas below John Day dam and above The Dalles dam. This data was supplemented with other survey data, the sources of which are noted in Table 89, and NOAA navigation charts near the dams (NOAA, 1983 and 1991). USGS "1-degree" digital elevation data (USGS, 1995) was used to establish island and shoreline elevations. Using the Arc/Info® GIS software system, the data was converted to a consistent coordinate system and datum, and combined to build a triangular irregular network (TIN), which represented the river bottom and shore as a three-dimensional surface. The resulting surface for The Dalles pool is shown in Figure 137. Once the surface was produced, it was “sampled” at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid

**Table 89. Columbia River bathymetry data sets used to create The Dalles pool bathymetric surface. Listed Figure numbers refers to the map which shows the survey location(s).**

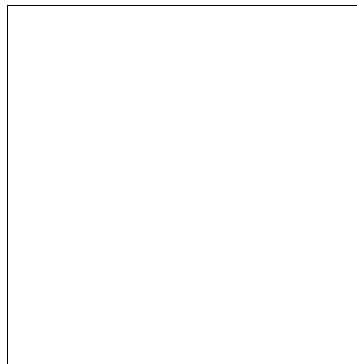
Bathymetric Data Set	Source	Survey Date	Approximate Rivermile	
			Start	End
The Dalles Pool Survey (Figure 138 and Figure 139)	George Kalli (Portland)	unknown	191.8	216.5
John Day Tailrace Survey (Figure 138)	Gregg Bertrand (Portland)	unknown	213.5	216.4
The Dalles Tailrace Survey (Figure 139)	Gregg Bertrand (Portland)	1981	191.0	192.5
John Day Pool Survey (Figure 138)	George Kalli (Portland)	unknown	216.5	292.5
John Day Forebay Surveys (Figure 138)	Gregg Bertrand (Portland)	unknown	216.5	226.0
Bonneville Pool Survey (Figure 139)	George Kalli (Portland)	unknown	148.0	191.7
Digitized NOAA Navigation Charts (Figure 138 and Figure 139)	Battelle	unknown	various	various



**Figure 137. Color representation of The Dalles pool bathymetric surface.**



**Figure 138. Bathymetric data near John Day dam.**



**Figure 139. Bathymetric data near The Dalles dam.**

## ***A.2 Calibration/Verification Data Sources***

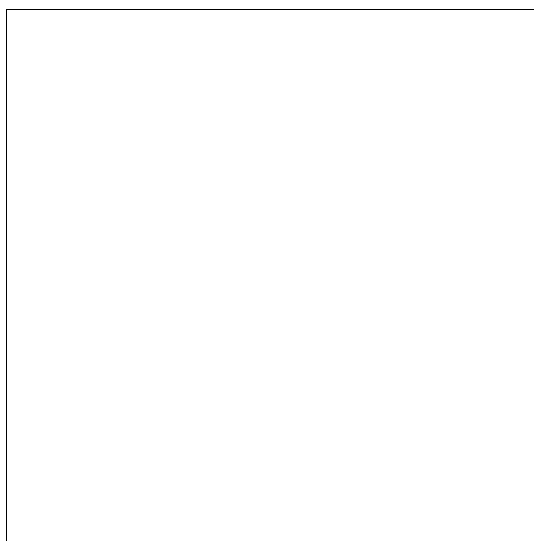
### ***A.2.1 Dissolved Gas Measurements***

Dissolved gas measurements were available from two sources: permanent fixed monitors and dissolved gas pool studies which used temporary monitors. Fixed monitor stations (FMS) in The Dalles pool area are shown in Figure 140. The water quality data recorded by the FMS included total dissolved gas (TDG) pressure, barometric pressure, and temperature, and was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file



/data3/dgas/database/FMS\_data/FMS\_data.zip, dated August 25, 1998. Fixed monitor data was used to establish temperature and TDG concentration in powerhouse flow at the John Day dam model boundary.

The dissolved gas pool studies performed in The Dalles Pool to date are shown in Table 90 and their durations are shown graphically in Figure 141. During these studies water temperature and TDG pressures were measured at several locations within The Dalles pool. These periods were used for model calibration and verification and are discussed individually below. The water quality data gathered during these studies was obtained from the DGAS team ftp server, limnos.wes.army.mil, in the file /data3/dgas/database/field\_data/field\_data.zip, dated August 25, 1998.



**Figure 140. FMS locations in and around The Dalles pool.**

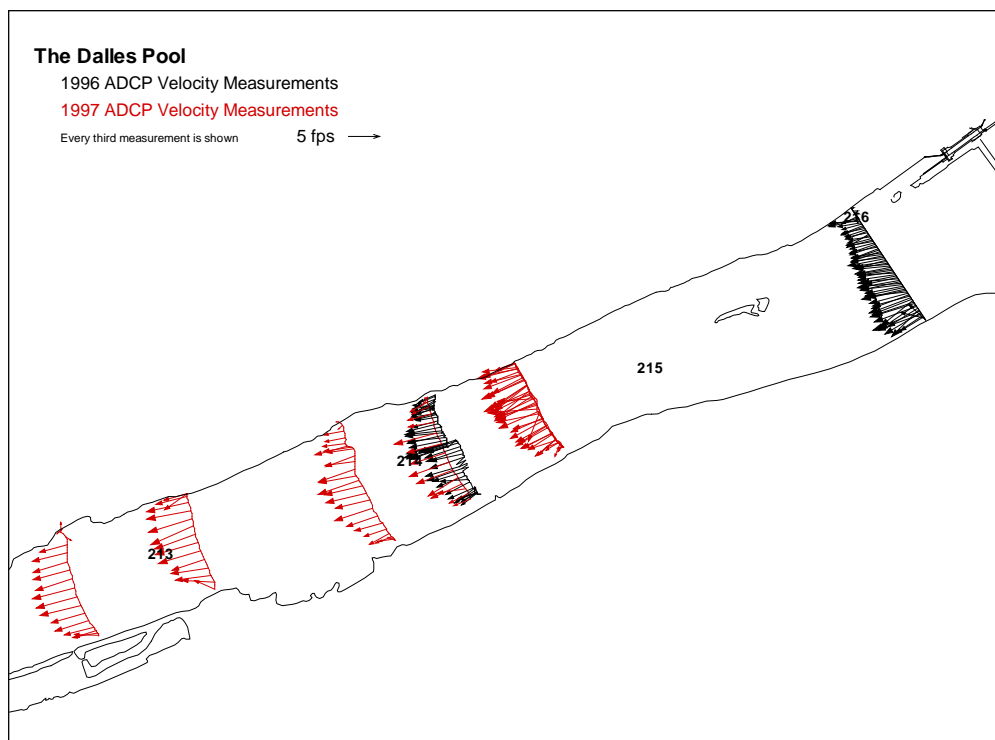
**Table 90. Dates of dissolved gas field studies in The Dalles pool.**

<b>STUDY SET</b>	<b>Start</b>	<b>End</b>
TDA SPR 96	5/24/96 4:53:00 PM	6/13/96 6:02:00 AM
TDA SUM 96	8/5/96 8:30:00 AM	8/15/96 11:14:00 AM
BON TDA SUM 97	6/19/97 4:00:00 PM	7/7/97 11:30:00 AM

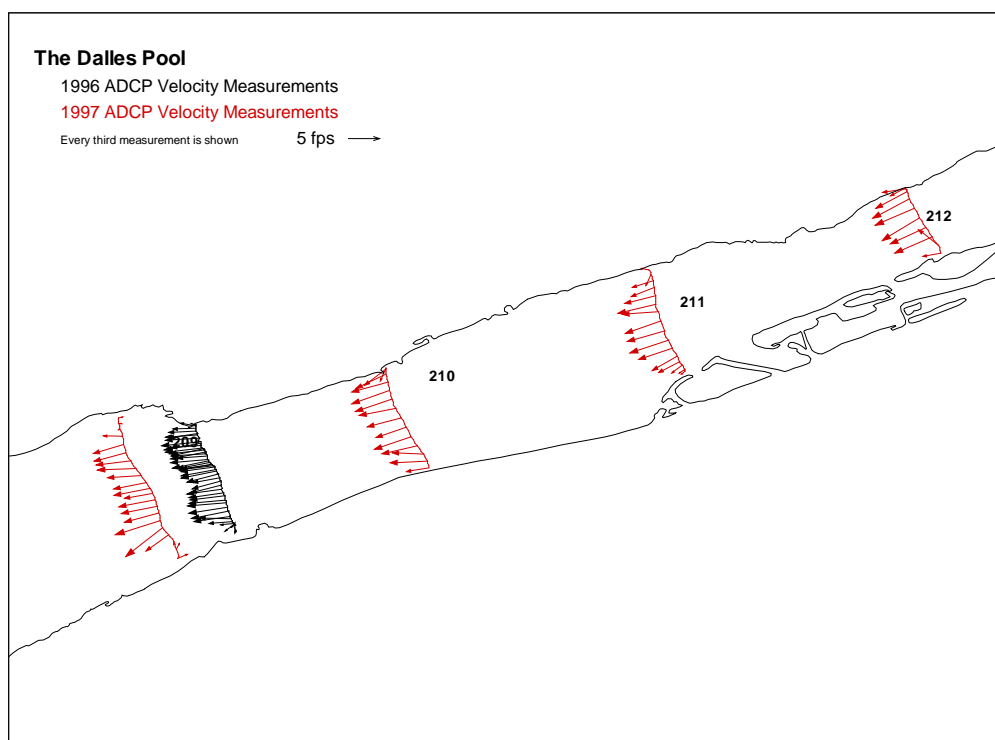
**Figure 141. Dates and durations of dissolved gas and ADCP velocity studies in The Dalles Pool**

*A.2.2 ADCP Velocity Measurements*

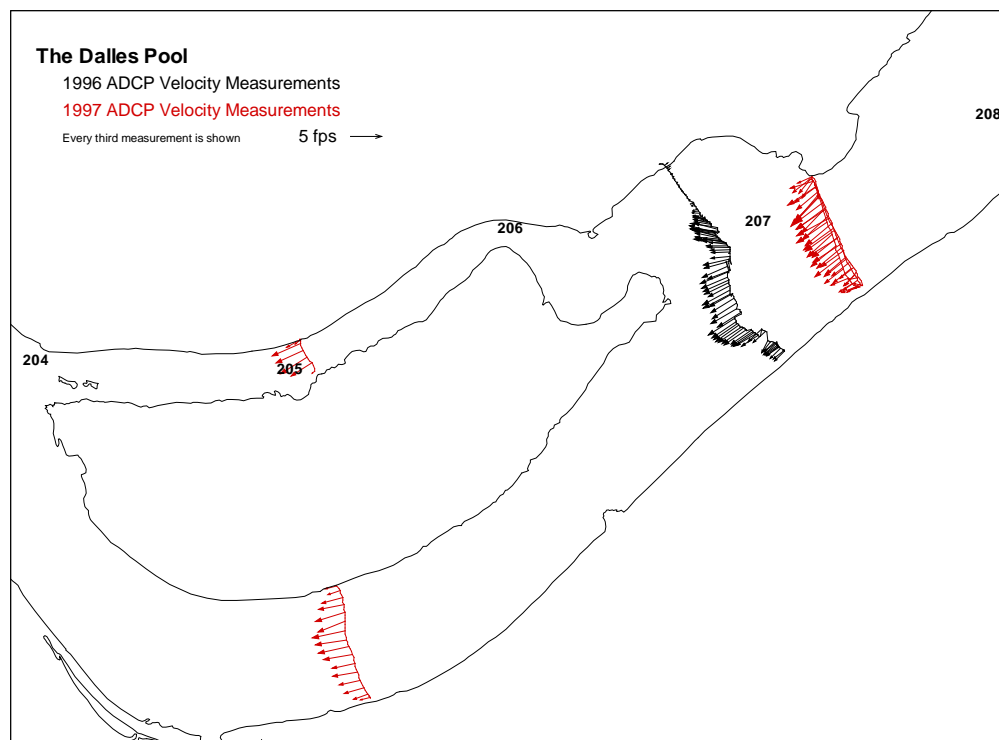
As shown in Figure 141, velocity measurements were taken using ADCP (Acoustic Doppler Current Profiler) instruments during two of the dissolved gas pool studies: Spring 1996 and Summer 1997. The ADCP data was obtained from the DGAS team FTP server, `limnos.wes.army.mil`, in the files `/data3/dgas/database/ADCP data/96ADCP.zip` and `/data3/dgas/database/ADCP data/97ADCP.zip`, dated April 10, 1998 and July 15, 1998, respectively. Figure 142 through Figure 147 show the measurements made as small arrows. The measurements were thinned for clarity in those figures: only one arrow in three was drawn.



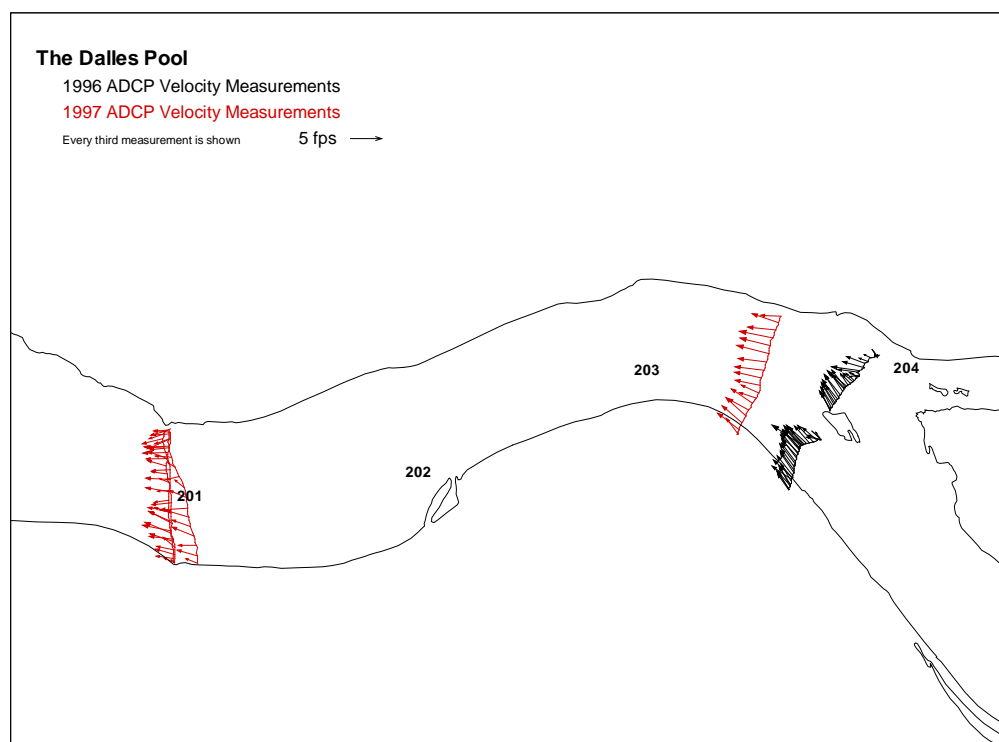
**Figure 142. The Dalles pool ADCP velocity measurements near John Day dam.**



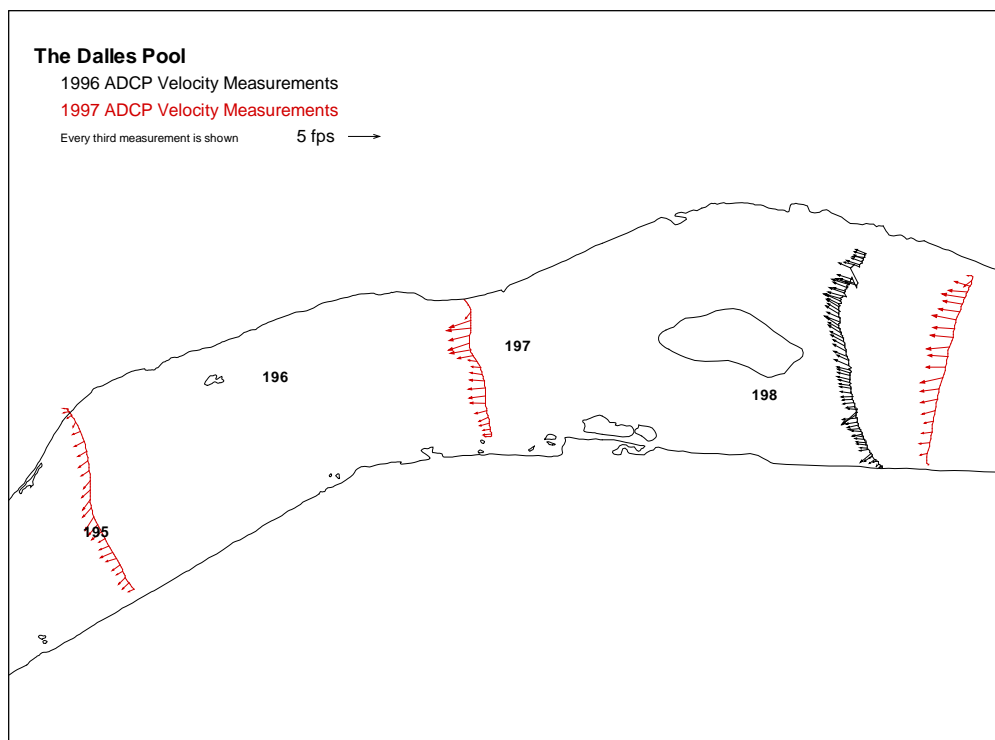
**Figure 143. The Dalles pool ADCP velocity measurements near Biggs.**



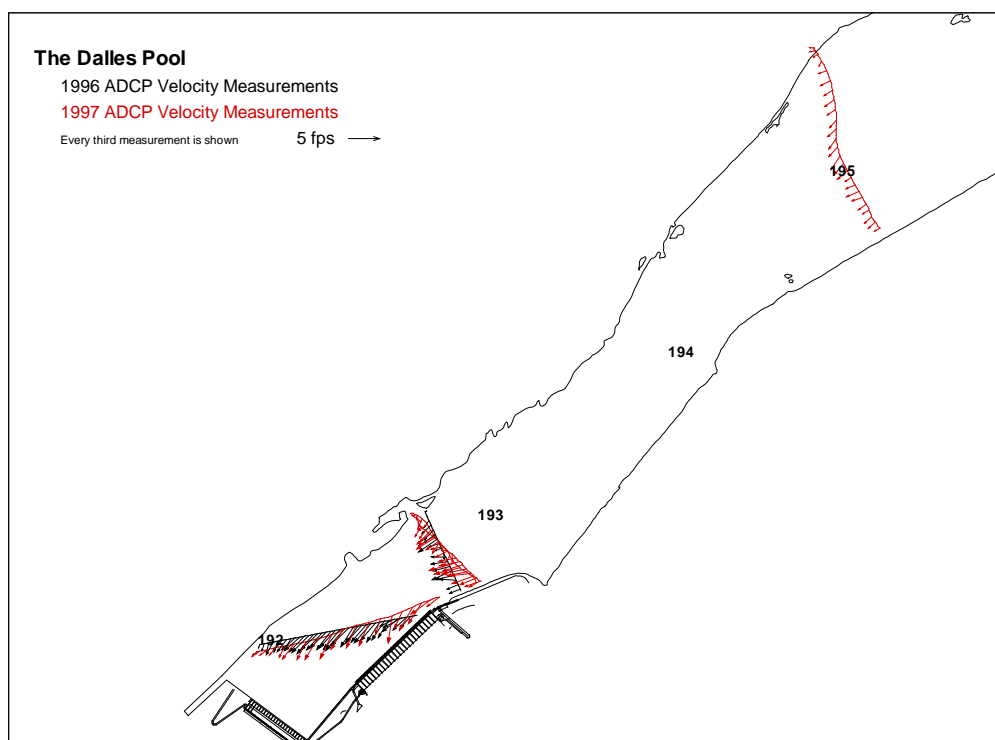
**Figure 144. The Dalles pool ADCP velocity measurements near Miller Island.**



**Figure 145. The Dalles pool ADCP velocity measurements near Celilo Falls.**



**Figure 146. The Dalles pool ADCP velocity measurements near Browns Island.**



**Figure 147. The Dalles pool ADCP velocity measurements near The Dalles dam.**

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### *A.2.3 Dam Operations Data*

Dam operations data was used to establish model boundary conditions. Hourly CHROMS data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file /data3/dgas/database/ops\_data/ops\_data.zip, dated August 25, 1998. The CHROMS operations data provided hourly aggregate spill and powerhouse flows and forebay and tailwater stages.

### *A.2.4 Weather Data*

Weather data was obtained from two DGAS team databases: one containing data from National Weather Service (NWS) stations, the other from WeatherPak instrumentation used for short periods during the pool studies. Both NWS and WeatherPak data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file /data3/dgas/database/weather\_data/weather\_data.zip, dated June 11, 1998.

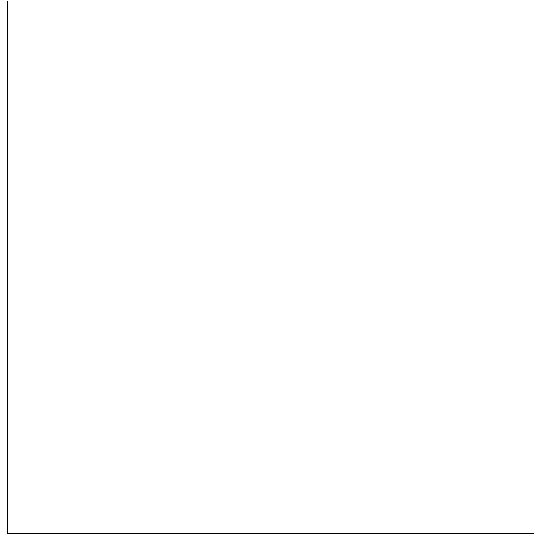
## Appendix B. Spring 1996 The Dalles Pool Study

### *B.1 Dissolved Gas Data*

The Spring 1996 The Dalles pool dissolved gas study started on May 24 and ended on June 7. A total of 21 water quality monitors were used. These stations, and their records, are listed in Table 89. Station locations are shown in Figure 148.

**Table 91. Dissolved gas monitor stations, and their records, used during the Spring 1996 The Dalles pool study.**

STATION	MinDate	MaxDate	Records
BON19175P	5/24/96 4:53:00 PM	6/13/96 6:02:00 AM	1452
JDADTDP	5/25/96 8:30:00 AM	6/2/96 8:27:00 PM	807
TDA20924P	5/25/96 9:30:00 AM	6/2/96 10:15:00 AM	772
TDA20923P	5/25/96 10:00:00 AM	6/2/96 10:00:00 AM	769
JDA21635P	5/25/96 10:44:00 AM	6/6/96 10:28:00 AM	1138
TDA20392P	5/25/96 1:30:00 PM	6/7/96 3:45:00 PM	1258
TDA20394P	5/25/96 2:00:00 PM	6/7/96 12:45:00 PM	1244
TDA20395P	5/25/96 2:30:00 PM	6/7/96 9:00:00 AM	1227
TDA19865P	5/25/96 6:15:00 PM	6/7/96 9:00:00 AM	1212
TDA19863P	5/25/96 6:45:00 PM	6/7/96 8:15:00 AM	1207
TDA19233P	5/25/96 7:15:00 PM	6/3/96 7:30:00 AM	817
TDA21471P	5/26/96 2:48:00 PM	6/1/96 6:26:00 AM	537
TDA21475P	5/26/96 3:23:00 PM	6/2/96 9:05:00 AM	640
TDA20391P	5/26/96 3:30:00 PM	6/7/96 1:45:00 PM	1146
TDA216010PP	5/26/96 4:00:00 PM	6/2/96 12:29:00 PM	651
TDA21601P	5/26/96 4:27:00 PM	6/2/96 12:56:00 PM	651
TDA21474P	5/26/96 7:30:00 PM	6/2/96 9:00:00 AM	631
TDA21608P	5/26/96 9:00:00 PM	6/2/96 12:45:00 PM	640
TDA21607P	5/26/96 9:33:00 PM	6/2/96 8:48:00 AM	622
TDA21606P	5/28/96 9:00:00 AM	6/2/96 1:15:00 PM	498
TDA21605P	5/28/96 9:15:00 AM	6/2/96 1:00:00 PM	494



**Figure 148. Dissolved gas monitor locations during the Spring 1996 study.**

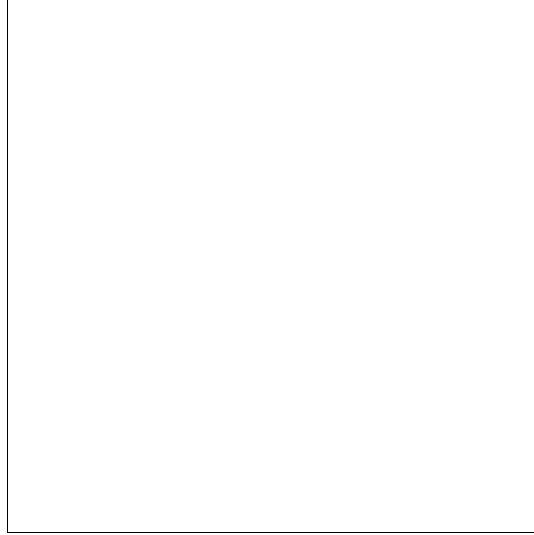
### ***B.2 Velocity Data***

Velocity measurements were made along a total of 9 transects during the Spring 1996 study period. The transects are summarized in Table 92. Supplied measurement locations are shown in Figure 149.

**Table 92. Summary of ADCP transects made during the Spring 1996 study period.**

DateLabel	Average Velocity	Depth	Number of Measurements
06-01-1996 10:08	3.1	58.3	107
06-01-1996 10:25	2.1	113.8	53
06-01-1996 12:47	1.9	47.0	208
06-01-1996 14:04	2.7	73.6	99
06-01-1996 14:35	3.6	30.8	103
06-01-1996 15:55	2.8	34.4	276
06-01-1996 16:39	4.6	32.0	136
06-01-1996 17:21	4.7	30.4	150
06-01-1996 18:24	4.9	32.5	233





**Figure 149. Locations of ADCP velocity measurements during the Spring 1996 study period.**

### ***B.3 John Day Dam Model Boundary***

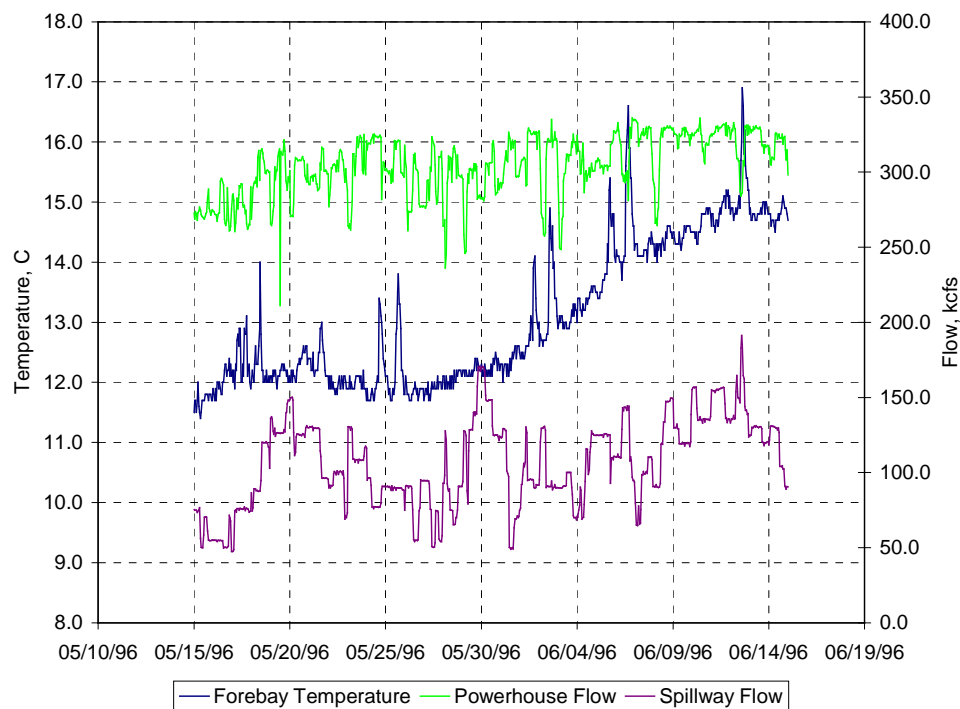
#### ***B.3.1 Dam Operations***

CHROMS operations data was used to establish the flow at the John Day dam model boundary and stage at The Dalles dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Spring 1996 study period are shown in Figure 150. These flows were uniformly distributed across the corresponding part of the model grid.

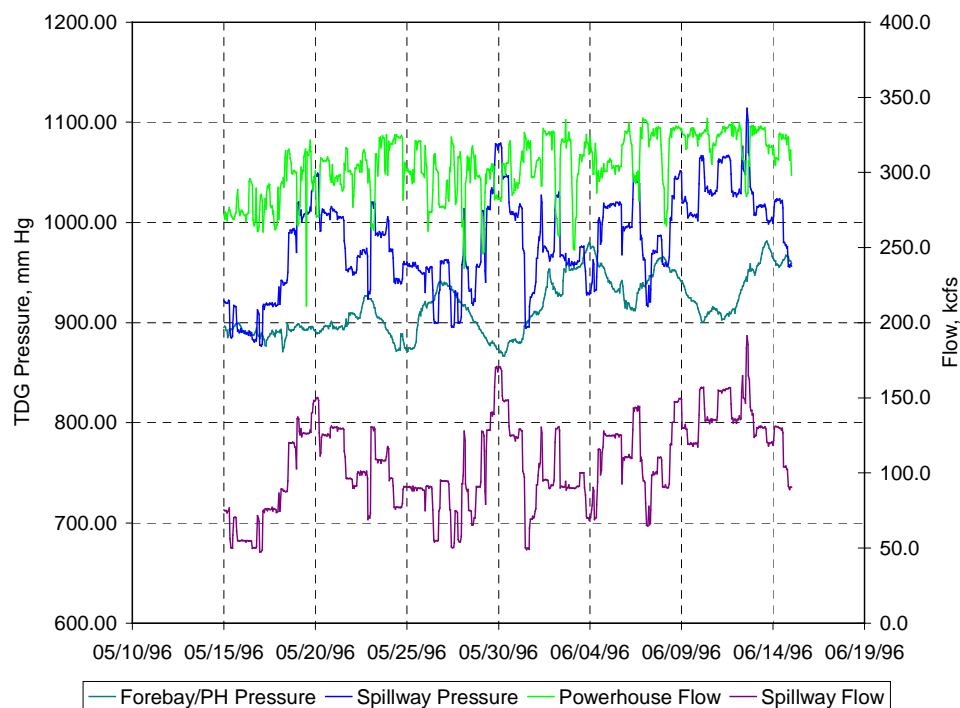
**Figure 150. John Day dam operations during the Spring 1996 study.**

*B.3.2 Water Quality*

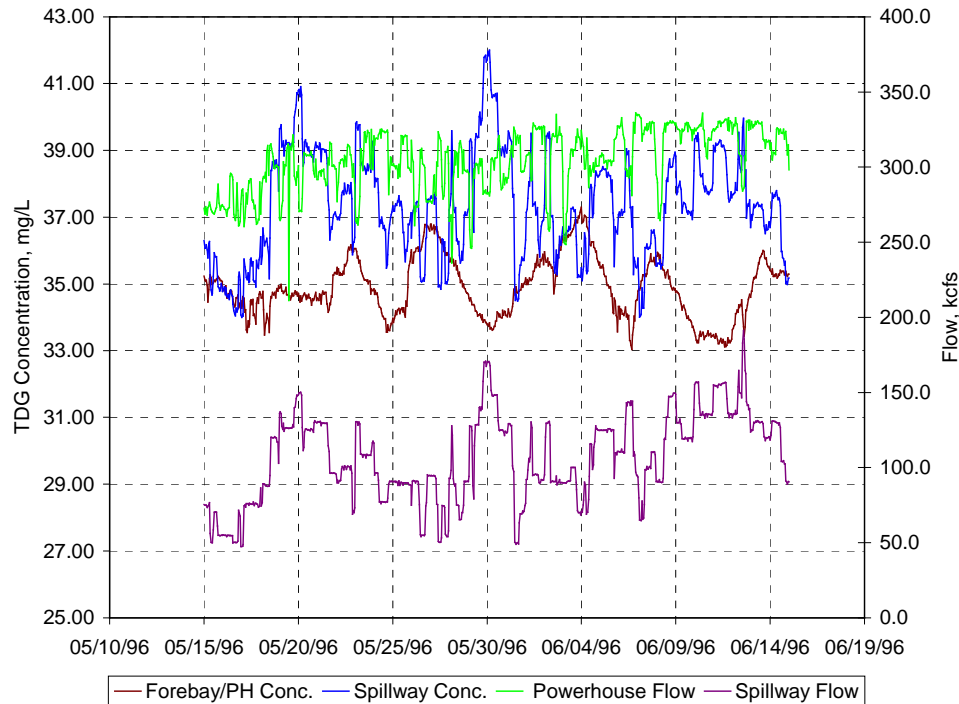
Initially, data from the permanent fixed monitor located in the John Day dam forebay (station name "JDA") was used to establish temperature at the John Day dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 151) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 152) was used to compute TDG concentrations (Figure 153) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 152 and Figure 153, respectively) were estimated using the TDG sourcing function for John Day dam.



**Figure 151. John Day forebay water temperature during the Spring 1996 study.**



**Figure 152. John Day forebay TDG pressure during the Spring 1996 study period.**

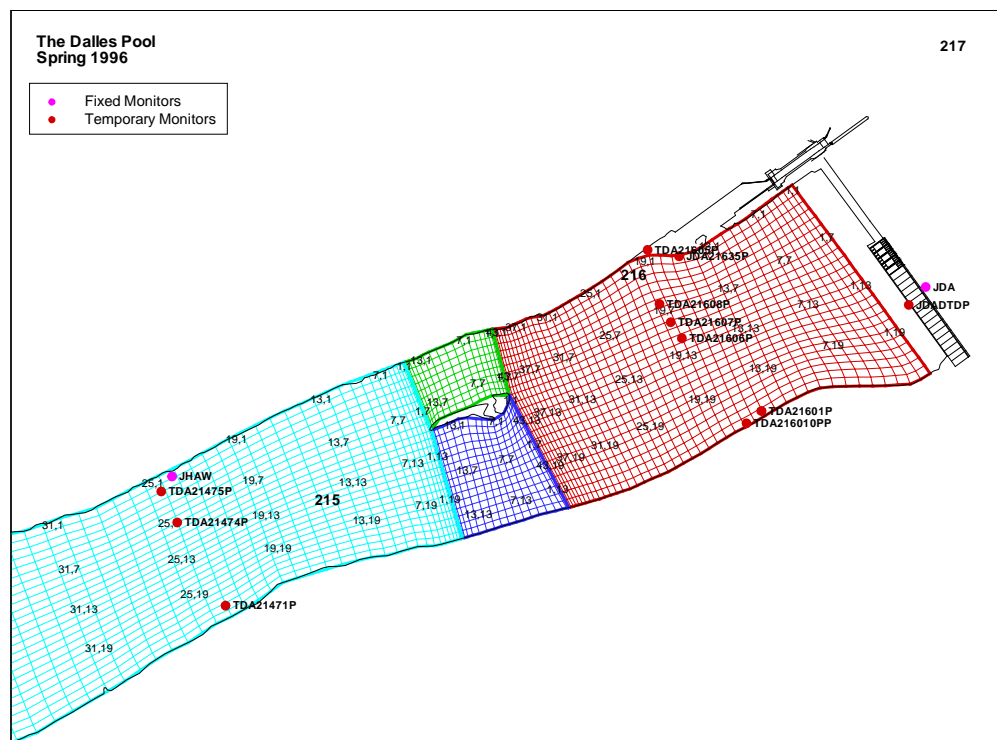


**Figure 153. Computed TDG concentration in the John Day forebay during the Spring 1996 study.**

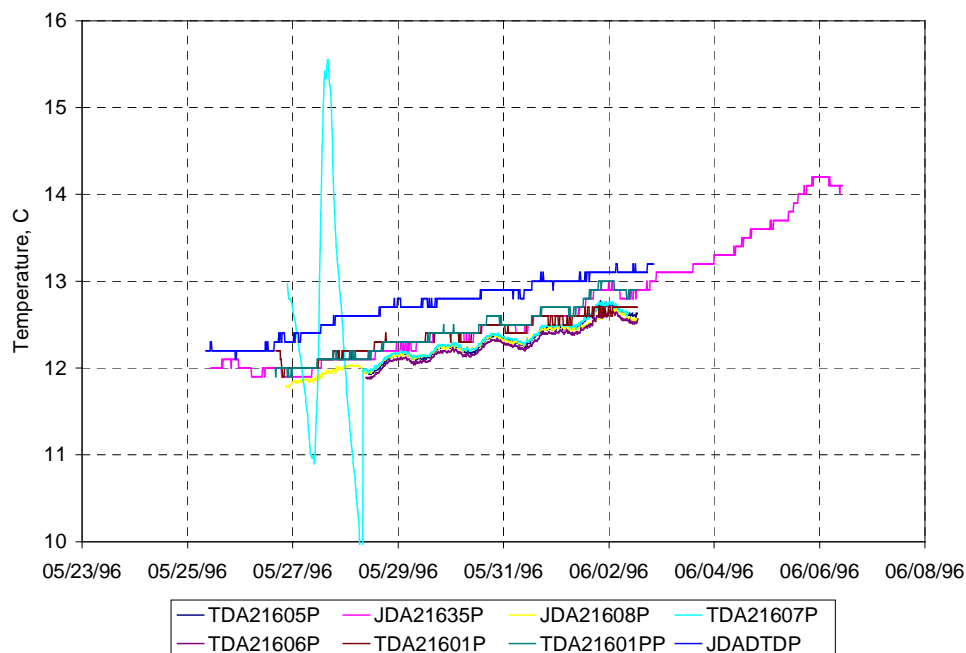
John Day dam model boundary temperature and dissolved gas concentrations were also established at the John Day dam boundary using the temporary pool study monitors. Eight temporary monitors were located in the John Day tailrace during Spring 1996 study period. In this case, the upstream transport simulation boundary was established at grid row 19 of block 1 (shown in cyan in Figure 154). Temporary monitor TDG concentrations and temperatures were applied as follows along that row of the model grid:

- JDA21635P to columns 1 to 3;
- TDA21474P to columns 4 to 7;
- TDA21607P to columns 8 to 9;
- TDA21606P to columns 10 to 12; and
- TDA21601P to columns 13 to 24.

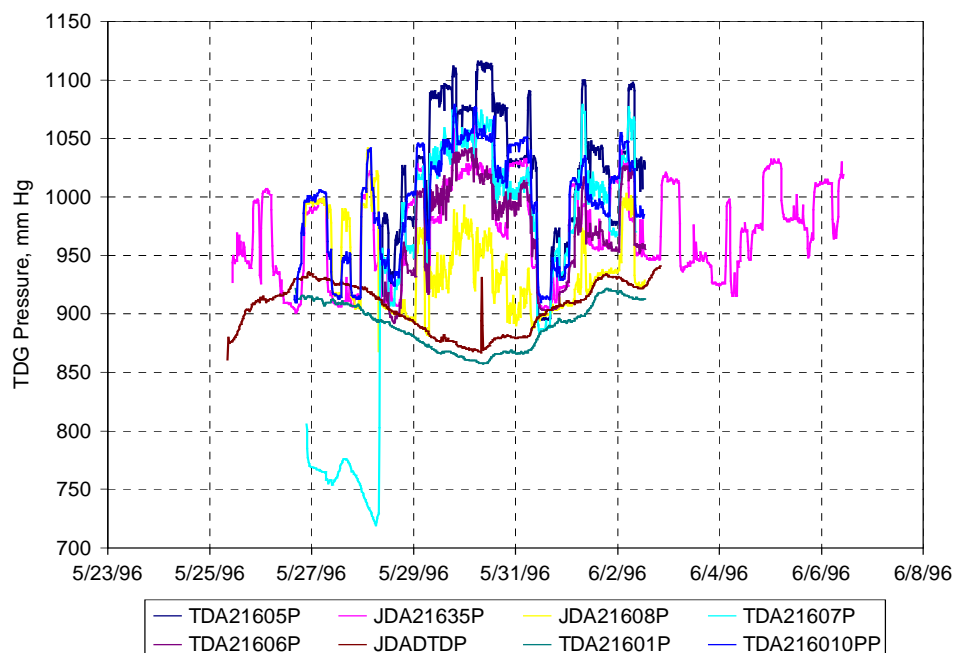
Station TDA21601PP was not used because its measured TDG pressures were incongruous with its location (see Figure 156).



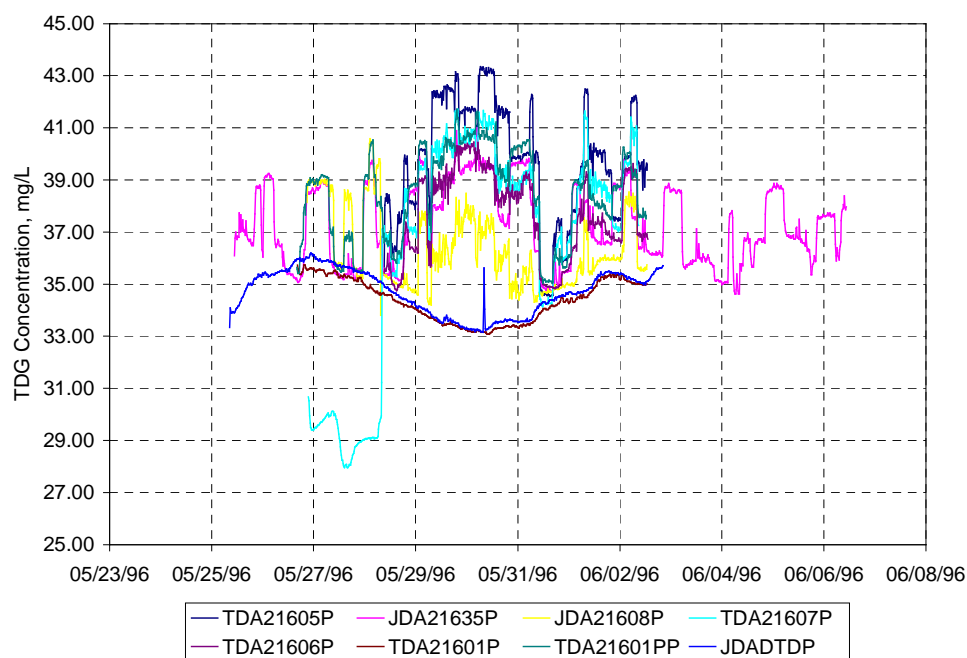
**Figure 154. Locations, relative to the model grid, of upstream temporary monitors during the Spring 1996 study period.**



**Figure 155. Temperatures measured by temporary monitors near John Day dam during the Spring 1996 study period.**



**Figure 156. TDG pressures measured by temporary monitors near John Day dam during the Spring 1996 study period.**



**Figure 157. TDG concentrations computed from temporary monitor data near John Day dam during the Spring 1996 study period.**

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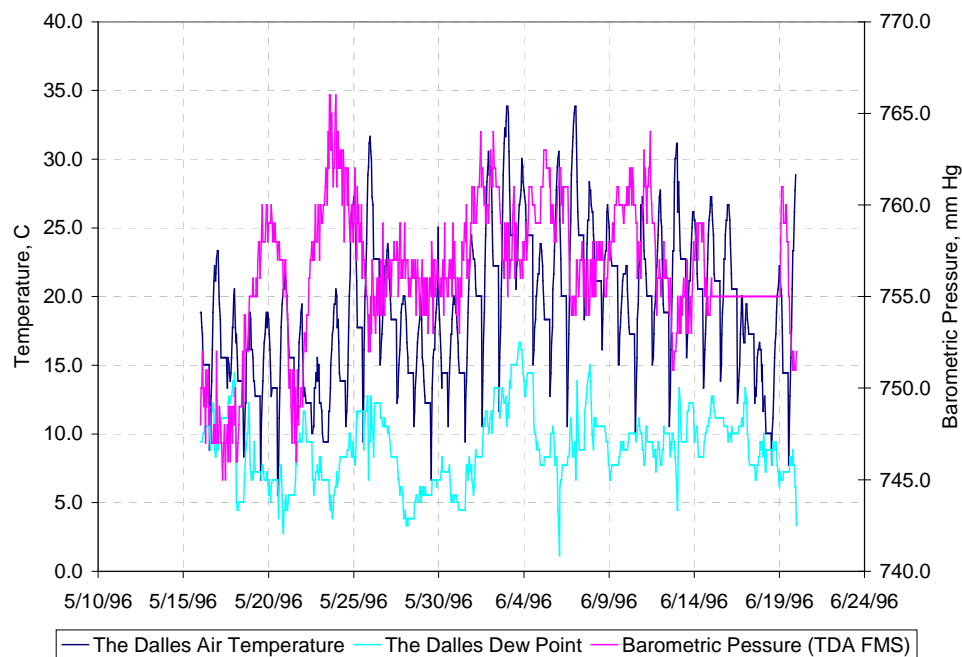
#### ***B.4 The Dalles Dam Boundary Operations***

Forebay stage for The Dalles dam was obtained from hourly CHROMS operations data and is shown in Figure 158.

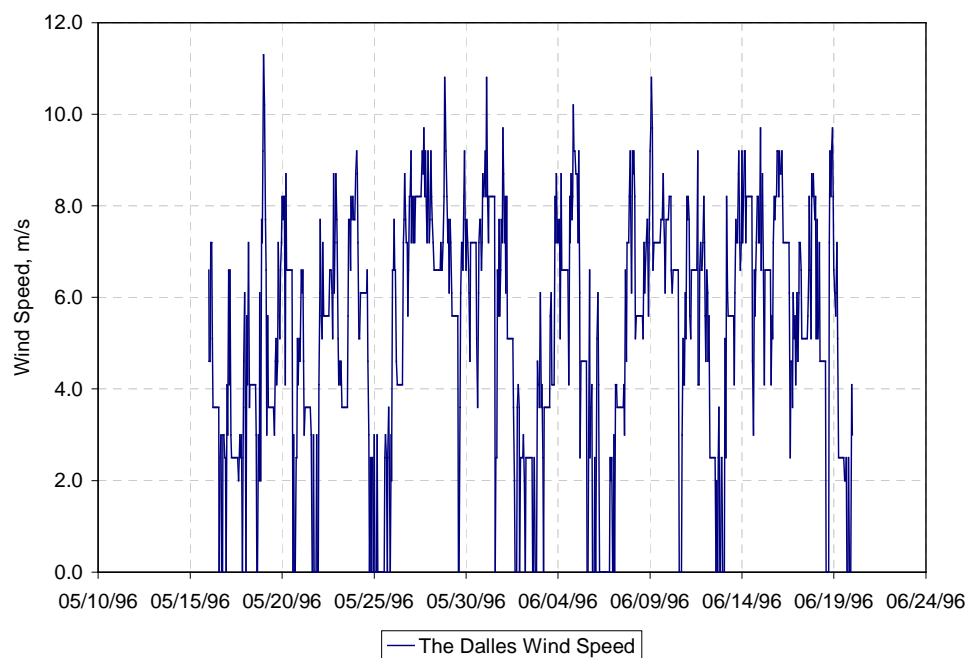
**Figure 158. The Dalles Dam operations during the spring 1996 study period.**

#### ***B.5 Weather***

Atmospheric conditions were considered constant over the entire pool. The Dalles, Oregon, air and dew point temperature (Figure 159) and wind speed (Figure 160) were used from the NWS weather database. Barometric pressure measured by the TDA FMS (also shown in Figure 159) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part the Spring 1996 study. The available radiation data was extended using NWS The Dalles dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 161.

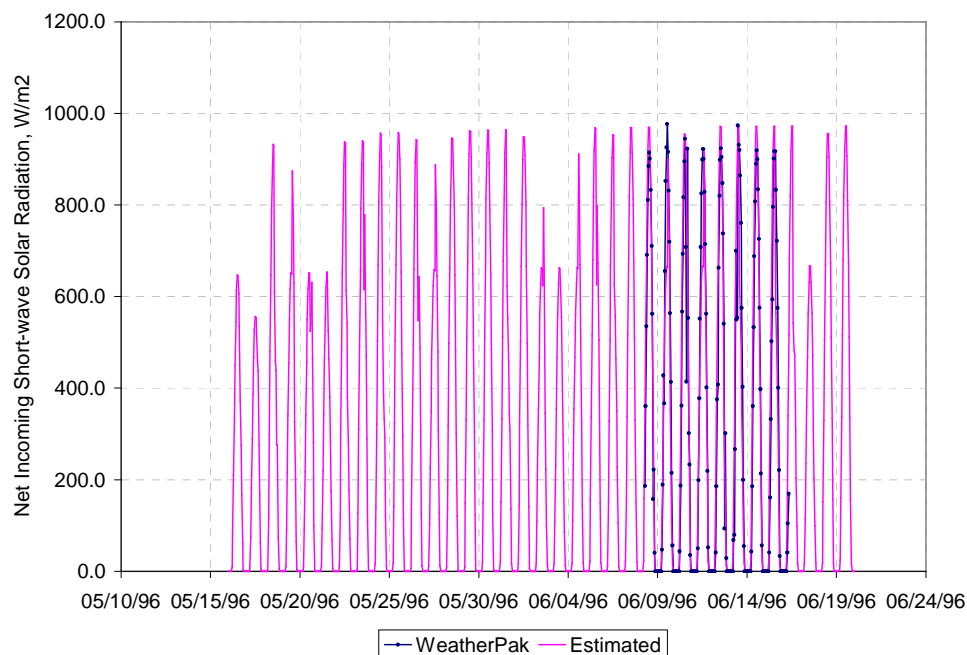


**Figure 159. Air temperature, dew point, and barometric pressure used during the Spring 1996 study period.**



**Figure 160. Wind speed used during the Spring 1996 study period.**





**Figure 161. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1996 study period.**

## Appendix C. Summer 1996 The Dalles Pool Study

### C.1 DGAS Data

The Summer 1996 The Dalles pool dissolved gas study started on July 1 and ended on July 12. A total of 14 water quality monitors were used. These stations, and their records, are listed in Table 93. Station locations are shown in Figure 162.

**Table 93. Dissolved gas monitor stations, and their records, used during the Summer 1996 The Dalles pool study.**

STATION	MinDate	MaxDate	Records
TDA19234P	8/5/96 8:30:00 AM	8/14/96 5:15:00 PM	900
TDA19953P	8/5/96 9:45:00 AM	8/14/96 9:30:00 AM	864
TDA20734P	8/6/96 7:00:00 AM	8/14/96 9:00:00 AM	776
TDA21165P	8/6/96 7:15:00 AM	8/14/96 8:30:00 AM	774
TDA21474P	8/6/96 10:12:00 AM	8/15/96 7:12:00 AM	852
TDA21585P	8/6/96 10:30:00 AM	8/15/96 8:15:00 AM	856
TDA21471P	8/6/96 10:52:00 AM	8/15/96 7:22:00 AM	851
TDA21604P	8/6/96 11:15:00 AM	8/15/96 9:00:00 AM	854
TDA21602P	8/6/96 11:30:00 AM	8/15/96 8:30:00 AM	853
TDA21473P	8/6/96 11:44:00 AM	8/15/96 6:59:00 AM	846
TDA21603P	8/6/96 12:38:00 PM	8/15/96 8:53:00 AM	850
TDA21639P	8/6/96 3:07:00 PM	8/15/96 9:24:00 AM	832
JDADTDP	8/6/96 3:22:00 PM	8/15/96 10:09:00 AM	834
JDA21653P	8/7/96 9:23:00 AM	8/15/96 11:14:00 AM	767

### C.2 Velocity Data

Velocity measurements were not made during the Summer 1996 study period.

**Figure 162. Dissolved gas monitor locations during the Summer 1996 study.**

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### ***C.3 John Day Dam Boundary***

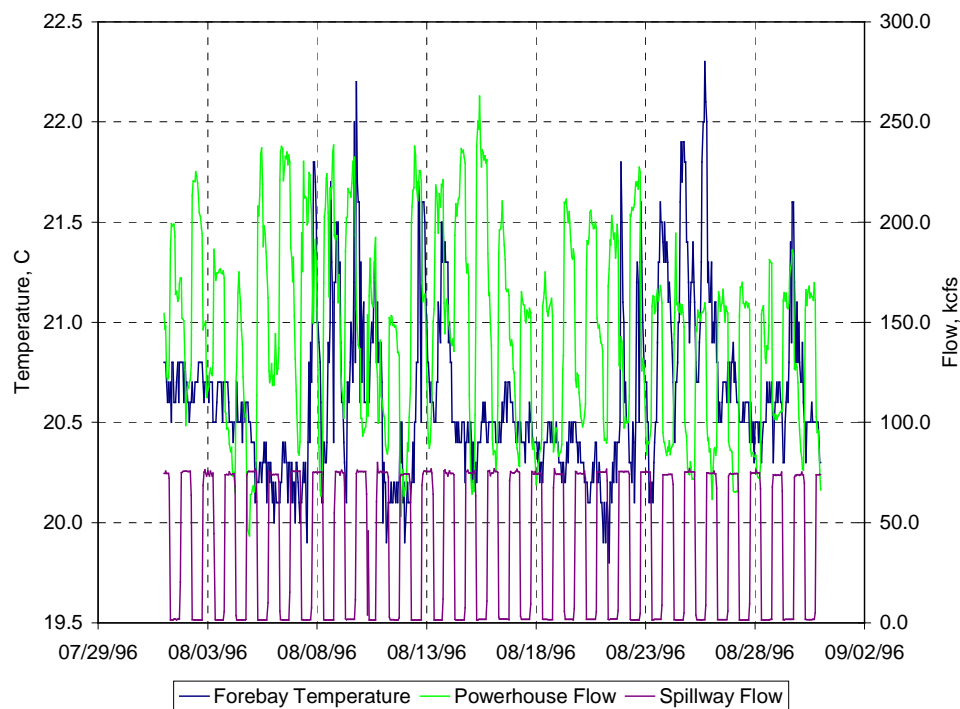
#### ***C.3.1 Discharge***

CHROMS operations data was used to establish the flow at the John Day dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Summer 1996 study period are shown in Figure 163. These flows were uniformly distributed across the corresponding part of the model grid.

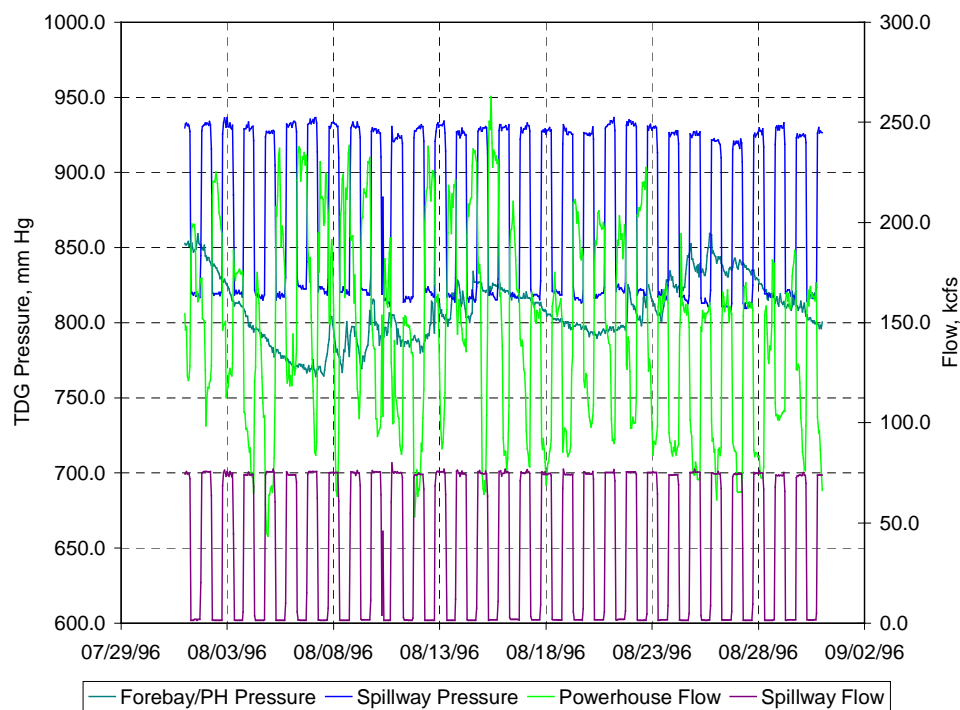
**Figure 163. John Day dam operations during the Summer 1996 study.**

#### ***C.3.2 Water Quality***

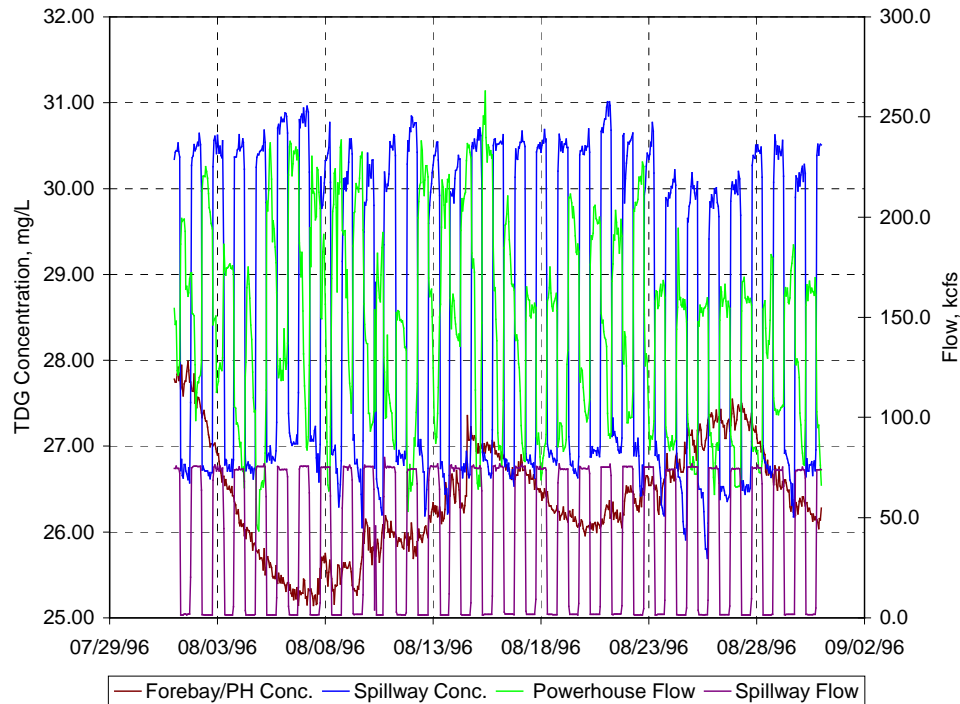
Initially, data from the permanent fixed monitor located in the John Day dam forebay (station name "JDA") was used to establish temperature at the John Day dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 164) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 165) was used to compute TDG concentrations (Figure 166) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 165 and Figure 166, respectively) were estimated using the TDG sourcing function for John Day dam.



**Figure 164. Water temperature at John Day dam during the Summer 1996 study.**



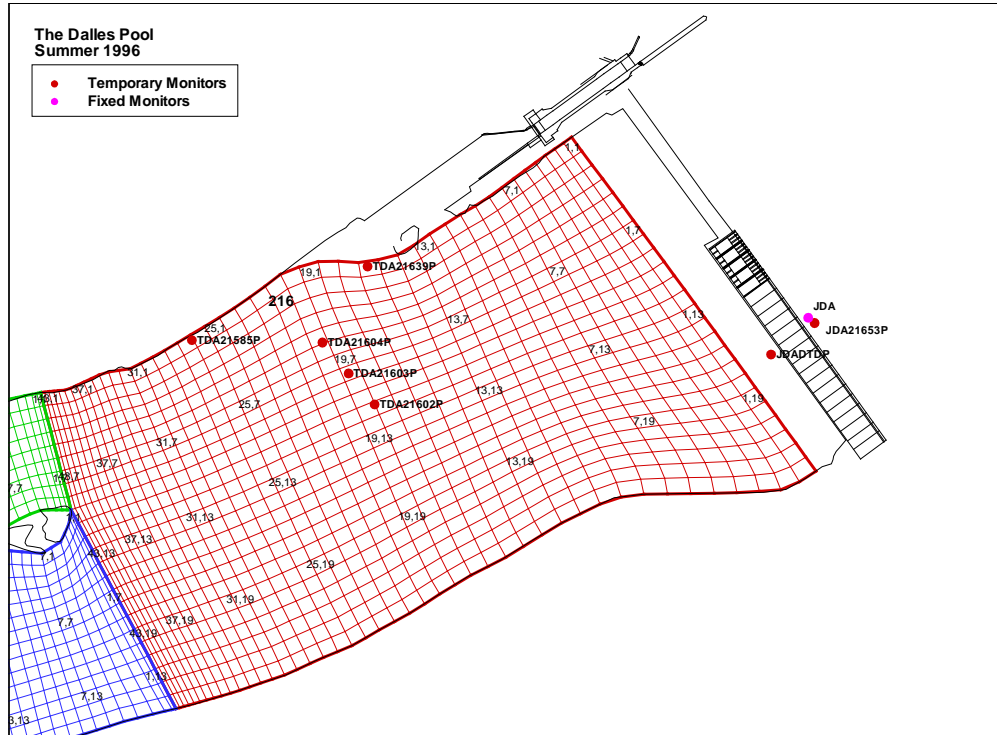
**Figure 165. TDG pressure at John Day dam during the Summer 1996 study period.**



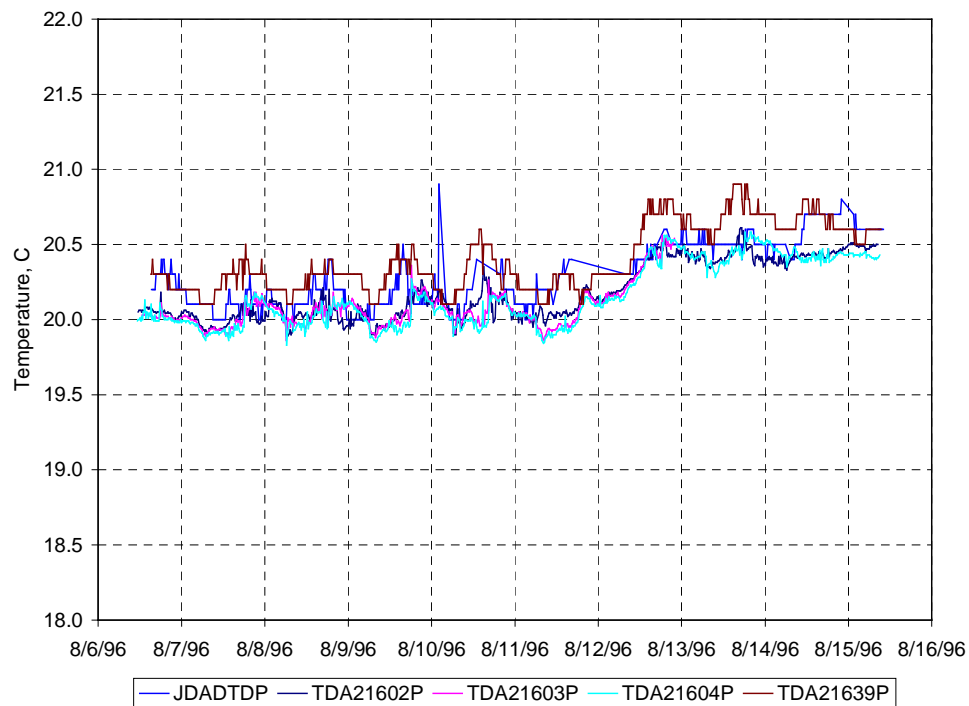
**Figure 166. Computed TDG concentration at John Day during the Summer 1996 study.**

John Day dam model boundary temperature and dissolved gas concentrations were also established at the John Day dam boundary using the temporary pool study monitors. Five temporary monitors were located in the John Day tailrace during Summer 1996 study period, as shown in Figure 167 (station TDA21585P was not used for establishing boundary conditions). The temperatures and TDG pressures recorded by these monitors are shown in Figure 168 and Figure 169, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 170. The transport simulation boundary was established at grid row 19 of block 1 (shown in red in Figure 170). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

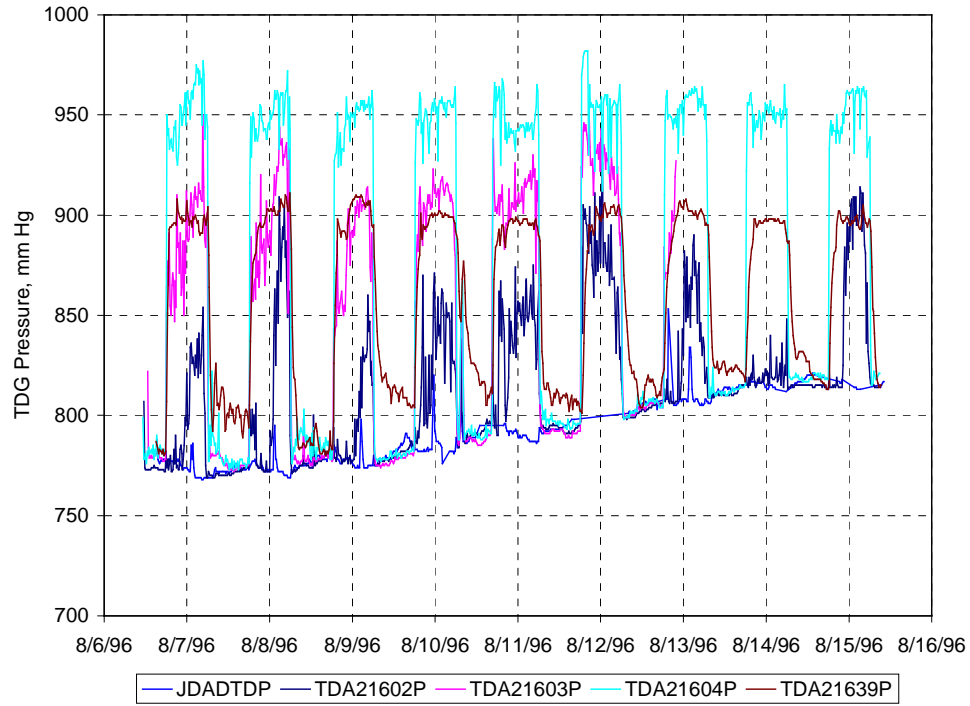
- TDA21639P: columns 1 to 3;
- TDA21604P: columns 4 to 6;
- TDA21603P: columns 7 to 9;
- TDA21602P: columns 10 to 14; and
- JDADTDP: columns 15 to 24.



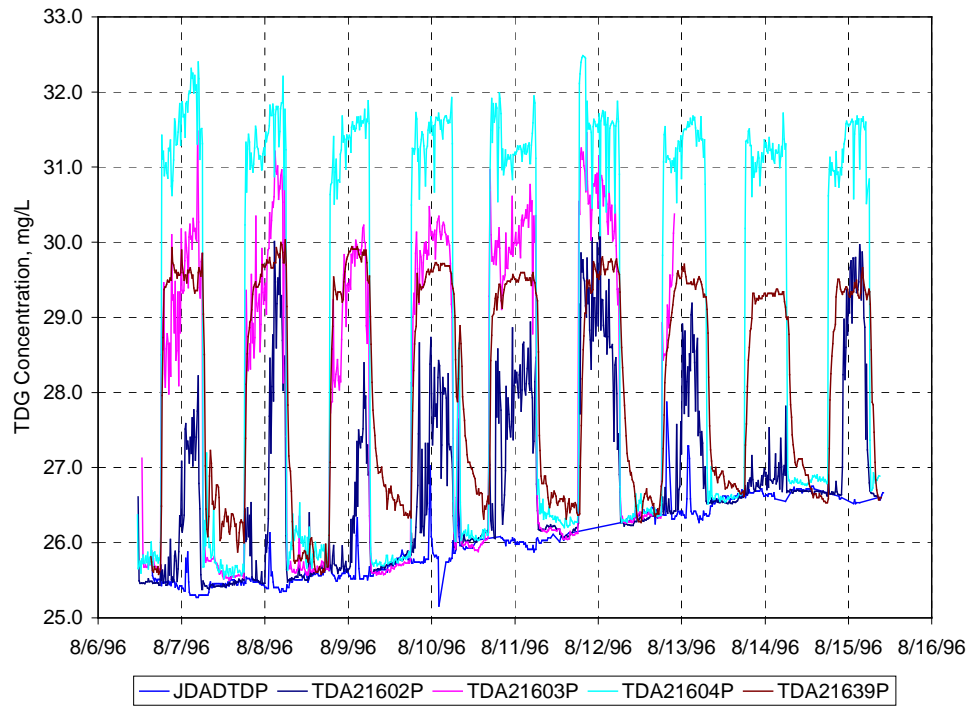
**Figure 167. Locations, relative to the model grid, of temporary monitors during the Summer 1996 study period.**



**Figure 168. Temperatures measured by temporary monitors near John Day dam during the Summer 1996 study period.**



**Figure 169. TDG pressures measured by temporary monitors near John Day dam during the Summer 1996 study period.**



**Figure 170. TDG concentrations computed from temporary monitor data near John Day dam during the Summer 1996 study period.**

#### ***C.4 The Dalles Dam Boundary Operations***

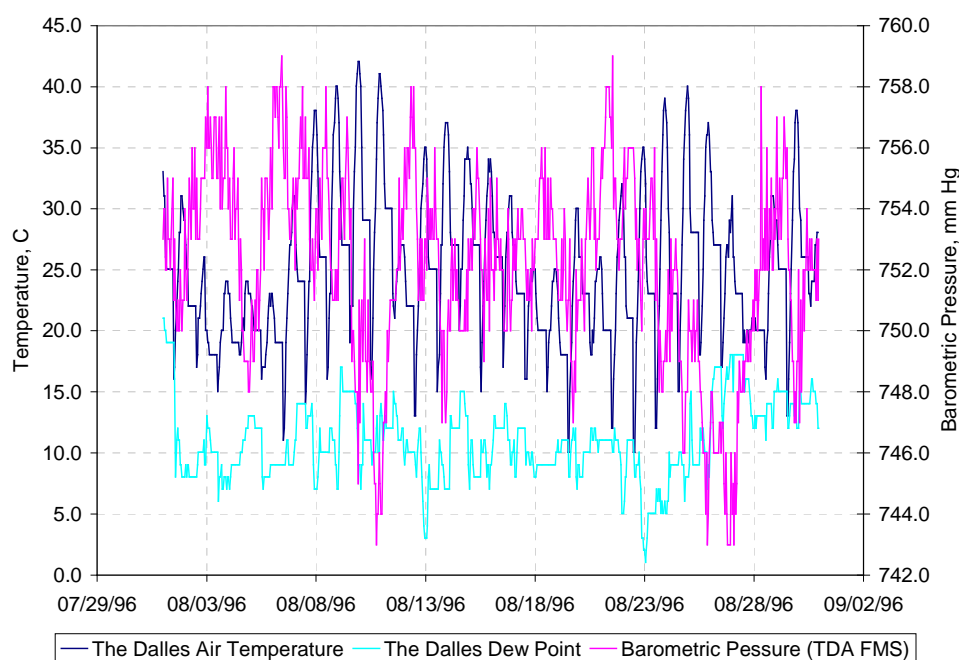
Forebay stage for The Dalles dam was obtained from hourly CHROMS operations data and is shown in Figure 171.

**Figure 171. The Dalles Dam operations during the Summer 1996 study period.**

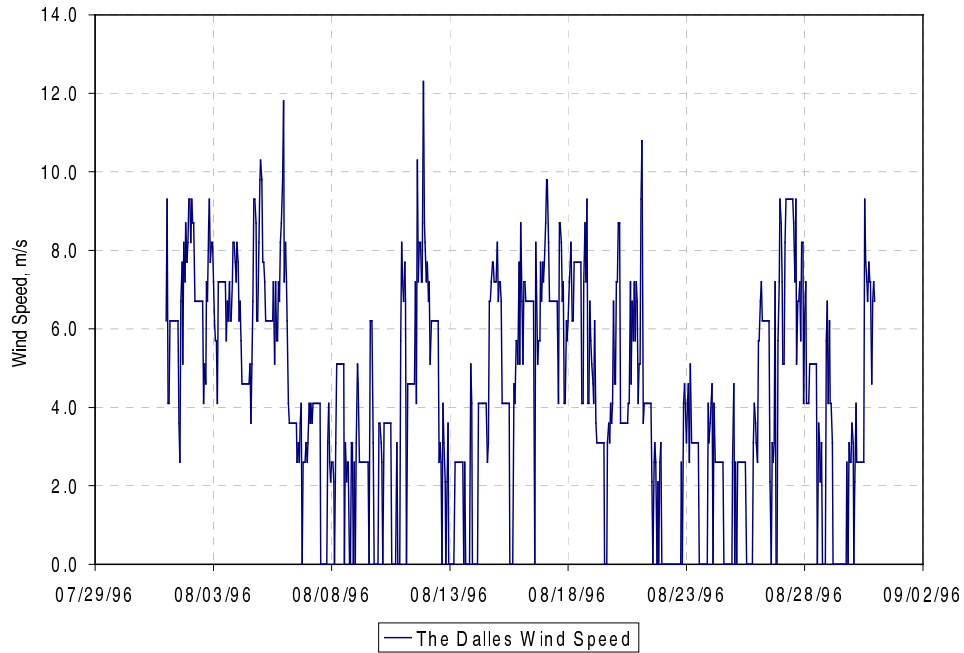


### C.5 Weather

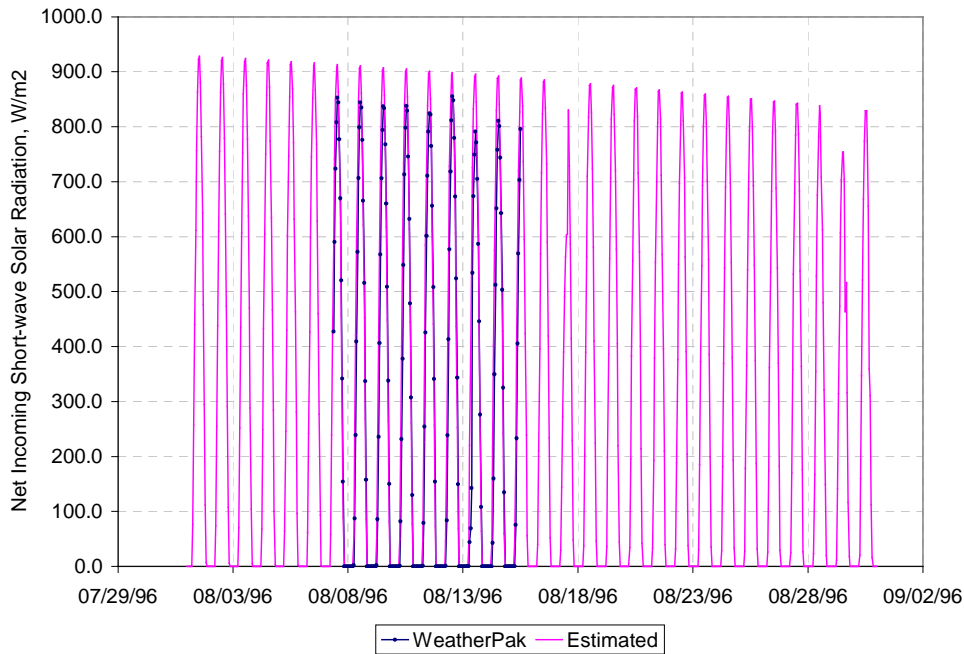
Atmospheric conditions were considered constant over the entire pool. The Dalles, Oregon, air and dew point temperature (Figure 172) and wind speed (Figure 173) were used from the NWS weather database. Barometric pressure (also shown in Figure 172), measured at the TDA FMS, was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for a short time during the Summer 1997 study. That record was extended by estimating total incoming radiation using NWS The Dalles dew point and cloud cover data. Cloud cover was assumed to be zero (clear skies) if cloud cover data was missing from the The Dalles record. Net incoming solar radiation based both on the estimated total solar radiation is shown in Figure 174.



**Figure 172. Air temperature, dew point, and barometric pressure used during the Summer 1996 study period.**



**Figure 173. Wind speed used during the Summer 1996 study period.**



**Figure 174. Net incoming short-wave solar radiation based estimated total radiation used during the Summer 1996 study period**

## Appendix D. Summer 1997 The Dalles Pool Study

### D.1 DGAS Data

The Summer 1997 The Dalles pool dissolved gas study started on July 1 and ended on July 12. A total of 16 water quality monitors were used in The Dalles pool. These stations, and their records, are listed in Table 94. Station locations are shown in Figure 175.

**Table 94. Dissolved gas monitor stations, and their records, used during the Summer 1997 The Dalles pool study.**

Station	Record Start	Record End	Number of Records
TDA21473P	6/19/97 4:00:00 PM	7/7/97 11:00:00 AM	1709
TDA21472P	6/19/97 4:00:00 PM	6/30/97 6:45:00 AM	1020
TDA21471P	6/19/97 4:00:00 PM	6/30/97 6:45:00 AM	1020
TDA20734P	6/19/97 4:00:00 PM	6/30/97 7:30:00 AM	1023
TDA20733P	6/19/97 4:00:00 PM	7/7/97 11:30:00 AM	1711
TDA20732P	6/19/97 4:00:00 PM	7/7/97 11:30:00 AM	1711
TDA20731P	6/19/97 4:00:00 PM	6/30/97 7:45:00 AM	1024
TDA21475P	6/19/97 4:00:00 PM	6/30/97 7:15:00 AM	1022
TDA21474P	6/19/97 4:15:00 PM	6/30/97 7:00:00 AM	1020
TDA20125P	6/20/97 8:30:00 AM	6/30/97 9:30:00 AM	961
TDA20124P	6/20/97 8:45:00 AM	6/30/97 9:15:00 AM	963
TDA20122P	6/20/97 9:00:00 AM	6/30/97 9:00:00 AM	960
TDA20121P	6/20/97 9:15:00 AM	6/30/97 8:45:00 AM	959
TDA19232P	6/20/97 10:15:00 AM	6/30/97 10:45:00 AM	963
TDA19234P	6/20/97 10:15:00 AM	6/30/97 10:30:00 AM	962
TDA19231P	6/20/97 3:45:00 PM	6/30/97 12:30:00 PM	948

### D.2 Velocity Data

Velocity measurements were made along a total of 26 transects during the Summer 1997 study period. The transects are summarized in Table 95. Supplied measurement locations are shown in Figure 176.

**Figure 175. Dissolved gas monitor locations during the Summer 1997 study.****Table 95. Summary of ADCP transects made during the Summer 1997 study period.**

DateLabel	Average		Number of
	Velocity	Depth	
Measurements			
06-24-1997 06:59	5.2	38.3	54
06-24-1997 07:06	5.4	34.3	45
06-24-1997 07:14	5.3	38.1	43
06-24-1997 07:25	4.5	30.3	46
06-24-1997 07:37	4.4	29.1	70
06-24-1997 07:53	6.0	33.5	43
06-24-1997 08:04	4.7	31.9	50
06-24-1997 08:16	5.0	47.2	29
06-24-1997 08:30	4.1	33.7	46
06-24-1997 08:45	5.5	33.0	41
06-24-1997 09:02	4.4	32.6	61
06-24-1997 09:22	4.1	32.5	44
06-24-1997 09:30	4.6	36.3	57
06-24-1997 09:36	4.0	33.4	39
06-24-1997 09:57	3.6	44.8	19
06-24-1997 10:14	4.1	39.5	54
06-24-1997 10:48	3.8	27.0	47
06-24-1997 11:30	2.8	59.6	47
06-24-1997 11:38	3.0	55.6	49
06-24-1997 11:45	2.9	55.1	48
06-24-1997 12:05	2.7	46.9	64
06-24-1997 12:24	2.2	63.7	64
06-24-1997 12:47	1.6	60.6	74
06-24-1997 13:22	2.2	120.6	47
06-24-1997 13:30	2.3	103.2	51
06-24-1997 13:39	2.9	52.3	58

**Figure 176. Locations of ADCP velocity measurements during the Summer 1997 study period.**

### ***D.3 John Day Dam Boundary***

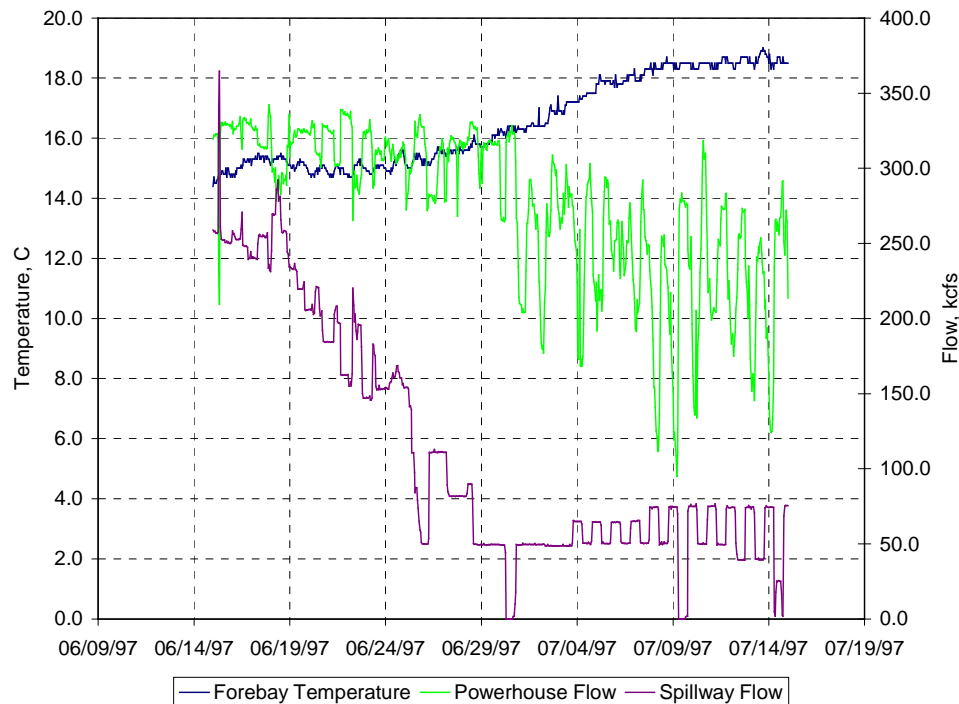
#### ***D.3.1 Discharge***

Hourly CHROMS operations data was used to establish the flow at the John Day dam model boundary. This data provided hourly aggregate spillway and powerhouse flow. Hourly spill and powerhouse flows for the Summer 1997 study period are shown in Figure 177. These flows were distributed uniformly across the corresponding part of the model grid.

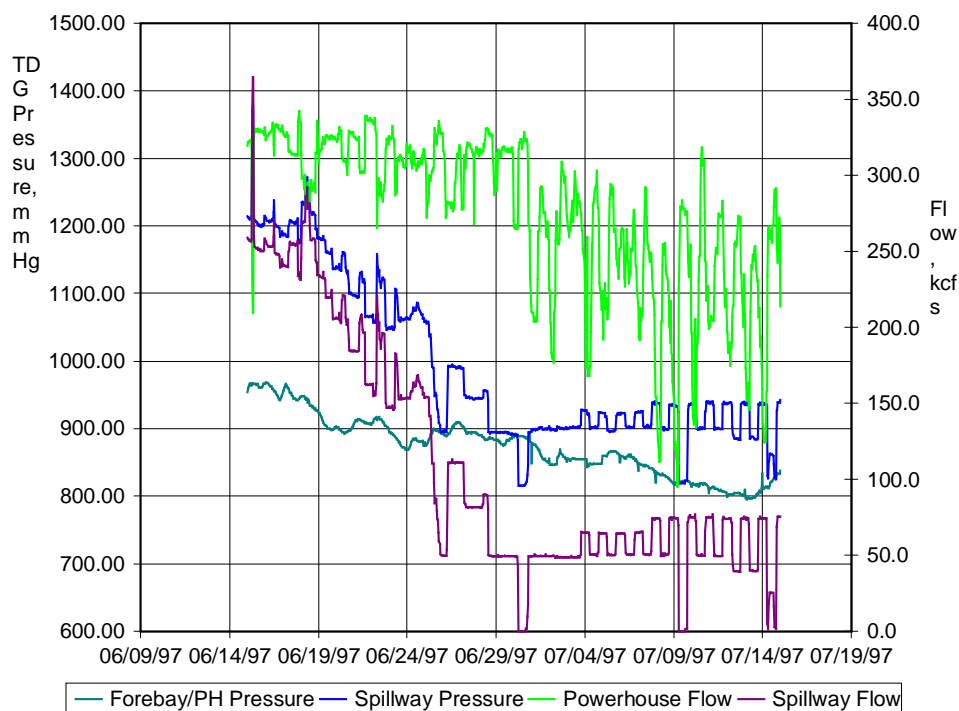
**Figure 177. John Day dam operations during the Summer 1997 study.**

### D.3.2 Water Quality

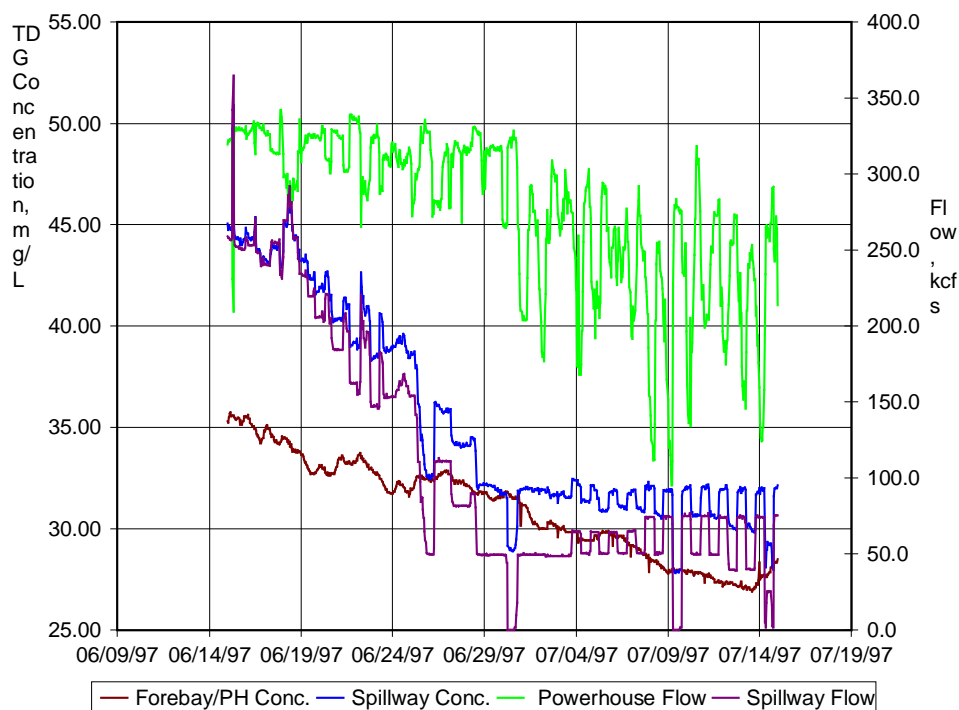
Initially, data from the permanent fixed monitor located in the John Day dam forebay (station name "JDA") was used to establish temperature at the John Day dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 178) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 179) were used to compute TDG concentrations (Figure 180) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 179 and Figure 180, respectively) were estimated using the TDG sourcing function for John Day dam.



**Figure 178. Water temperature at John Day dam during the Summer 1997 study.**



**Figure 179. TDG pressure at John Day dam during the Summer 1997 study period.**



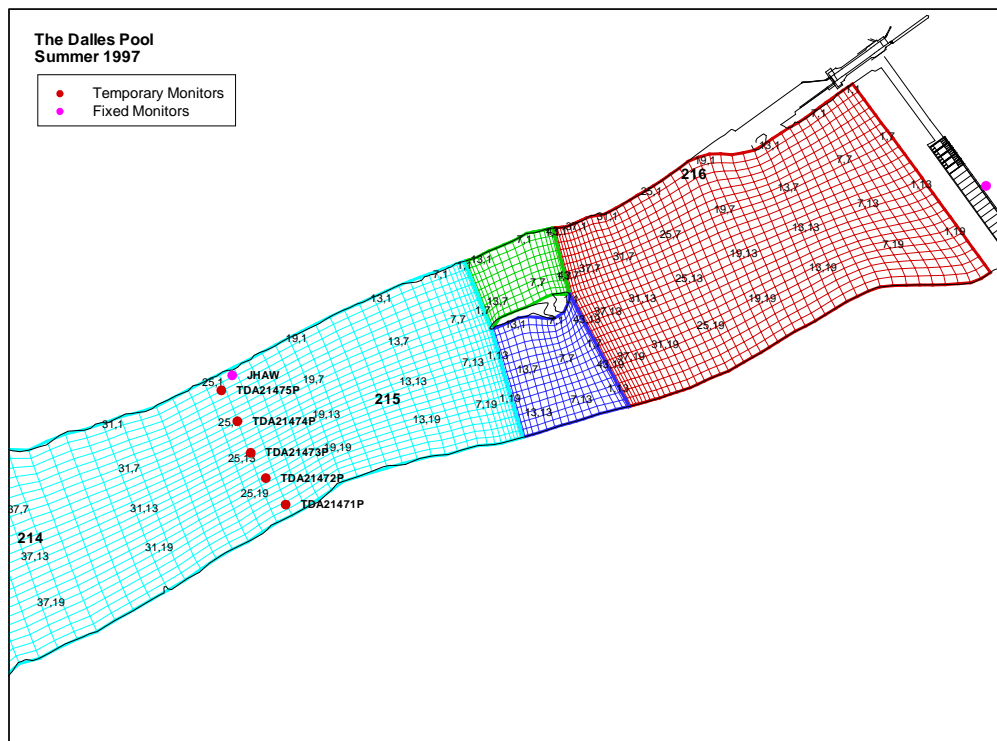
**Figure 180. Computed TDG concentration at John Day during the Summer 1997 study.**

John Day dam model boundary temperature and dissolved gas concentrations were also established at the John Day dam boundary using the temporary pool study monitors. Five temporary monitors were located about two miles below John Day dam during Spring 1996 study period, as shown in Figure 181. The temperatures and TDG pressures recorded by these monitors are shown in Figure 182 and Figure 183, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 184.

The transport simulation boundary was established at grid row 24 of block 4 (shown in cyan in Figure 181). Temporary monitor TDG concentrations and temperatures were applied as follows along that row of the model grid:

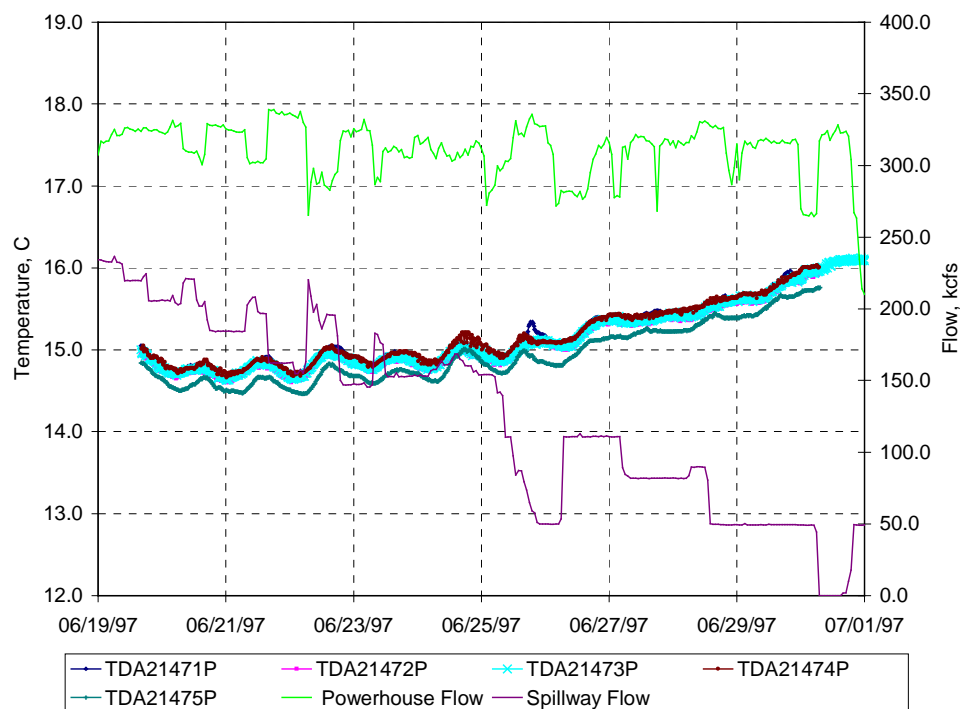
- : TDA21475P columns 1 to 4;
- : TDA21474P columns 5 to 9;
- : TDA21472P columns 10 to 18; and
- : TDA21471P columns 19 to 24.

Station TDA21473P was not used because of the very erratic TDG pressures it recorded (see Figure 183).

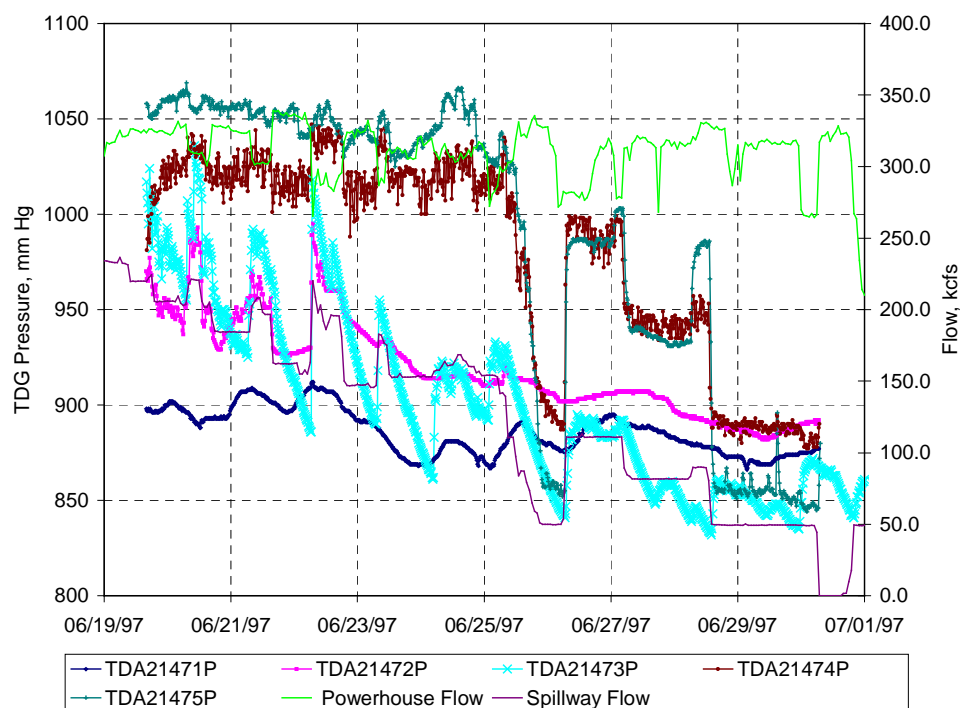


**Figure 181. Locations, relative to the model grid, of temporary monitors during the Summer 1997 study period.**

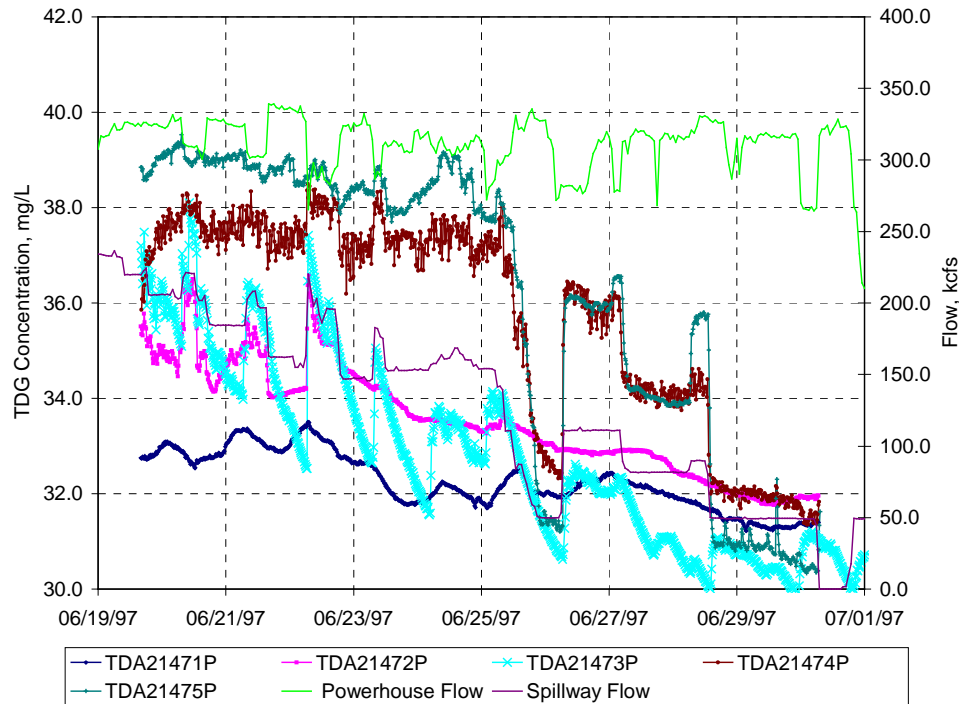




**Figure 182. Water temperature measured by temporary monitors below John Day dam during the Summer 1997 study.**



**Figure 183. TDG pressure measured by temporary monitors below John Day dam during the Summer 1997 study period.**



**Figure 184. TDG concentration computed using temperature and pressure measured by temporary monitors below John Day during the Summer 1997 study.**

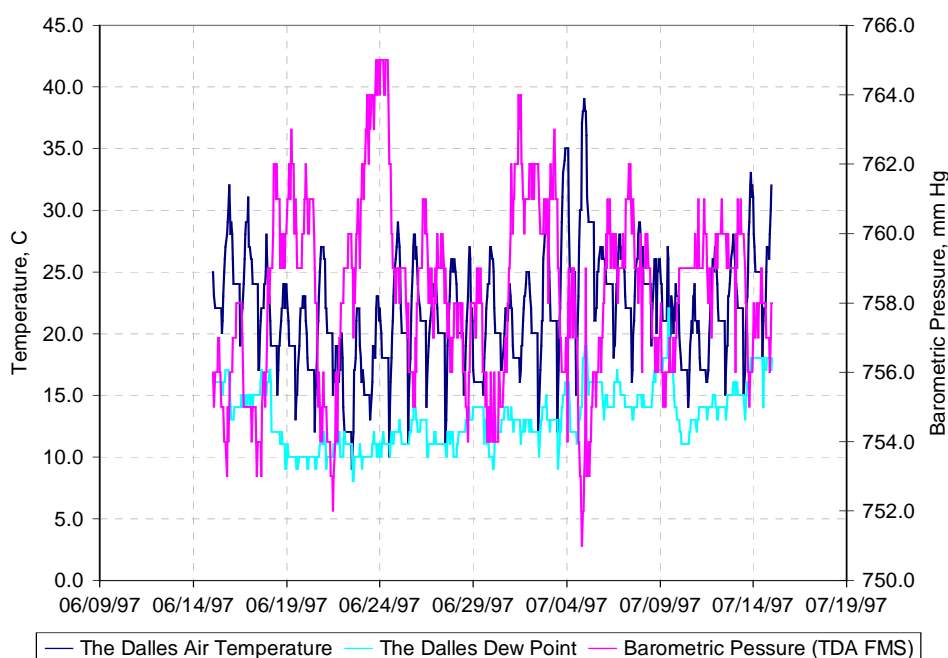
#### ***D.4 The Dalles Dam Boundary Operations***

Forebay stage for The Dalles dam was obtained from hourly CHROMS operations data and is shown in Figure 185.

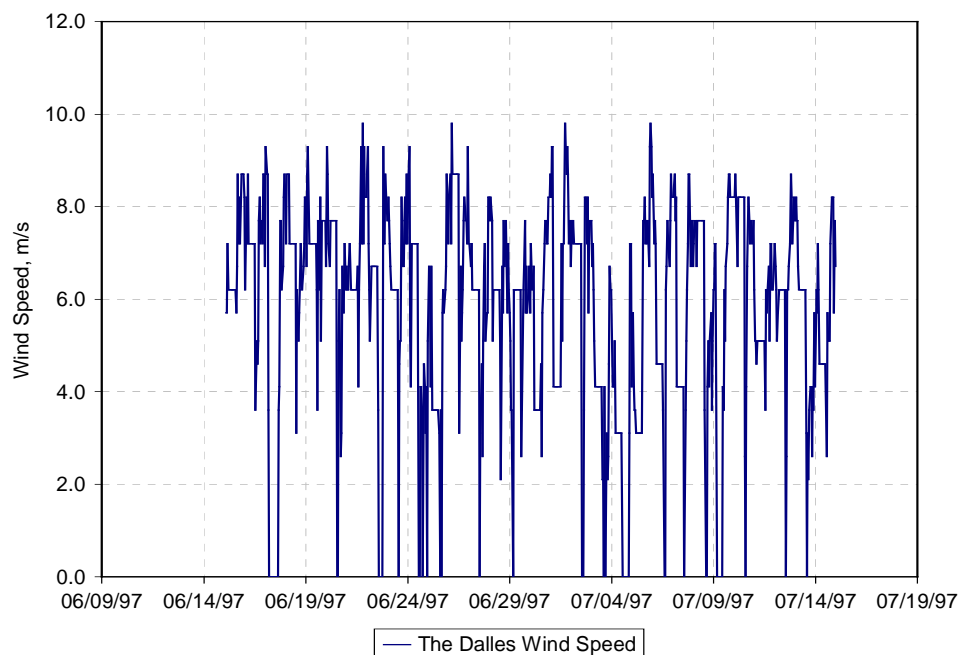
**Figure 185. The Dalles Dam operations during the Summer 1997 study period.**

### D.5 Weather

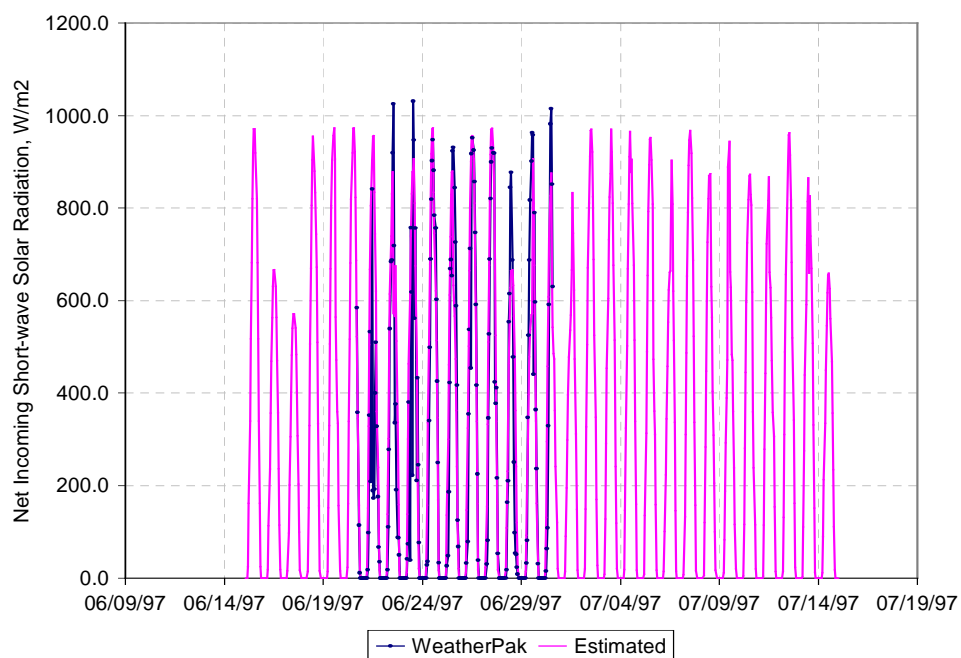
Atmospheric conditions were considered constant over the entire pool. The Dalles, Oregon, air and dew point temperature (Figure 186) and wind speed (Figure 187) were used from the NWS weather database. Barometric pressure (also shown in Figure 186), measured at the TDA FMS, was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for a short time during the Summer 1997 study. That record was extended by estimating total incoming radiation using NWS The Dalles dew point and cloud cover data. Cloud cover was assumed to be zero (clear skies) if cloud cover data was missing from the The Dalles record. Net incoming solar radiation based both on the estimated total solar radiation is shown in Figure 188.



**Figure 186. Air temperature, dew point, and barometric pressure used during the Summer 1997 study period.**



**Figure 187. Wind speed used during the Summer 1997 study period.**



**Figure 188. Measured and estimated net incoming short-wave solar radiation used during the Summer 1997 study period.**